COMPUTER AIDED PARAMETRIC STUDY OF FRAME STRUCTURES UNDER SETTLEMENT AND STIFFNESS VARIATIONS

BY

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, AHMADU BELLO UNIVERSITY, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER IN SCIENCE IN STRUCTURAL ENGINEERING

IN THE

DEPARTMENT OF CIVIL ENGINEERING
FACULTY OF ENGINEERING
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ZARIA - NIGERIA.

DECLARATION

I hereby declare that this thesis is a record of the research work carried out by me under the supervision of Prof. A.O. Abatan. To the best of my knowledge, it has not been previously published or accepted anywhere for the award of any degree.

All works, opinions and ideas other than mine have been fully acknowledged.

Imam, Mohammed Rafik Ibrahim bhai

CERTIFICATION

This thesis entitled "Computer Aided Parametric Study of Frame Structures Under Support Settlement and Stiffness Variations", by IMAM, M.R.I. meets with the regulations governing the award of the degree of Master of Science (Structural Engineering) of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

I gratefully dedicate this work to my teachers both here and abroad.

ACKNOWLEDGEMENT

This work is the result of the interest that I had cherished from the days of my undergraduate studies in structural analysis and behaviours. This interest has been further stimulated by my able supervisor and Head of Department Prof. A.O. Abatan. I am very grateful to him for giving me continued support and advice throughout the period of my project.

I must also express my special gratitude to Mr. A.A. Aziz , formerly a lecturer in the Department of Civil Engineering, whose criticism and comments prompted me to further define my project. I would also like to thank Dr. Adebisi, Dr. Oyetola, Mrs. Nytco, Mr. Sadeeq and the entire staff for their comments and encouragement in preparing the final dissertation.

It would certainly not be out of place to thank the Head of Department of Accounting and the Managing Directors of Mai and Associates for allowing me to use the IBM PC in their respective establishments.

Finally, mention should be made of Professor A. R. I. Doi, Director, C. I. L. S., Institute of Administration, Ahmadu Bello University, Zaria for his moral and material support.

JUNE, 1989. IMAM, M.R.I.

ABSTRACT

Computers have revolutionised many fields of scientific study. Engineering as a discipline has been one of the beneficiaries of the computers. In this study, efforts have been made to present a direct spring model approach to perform the parametric study of frame structures under a single support settlement and differential support settlements. In addition, the effects of different stiffnesses on distributions of displacements and forces of frame structures are also worked out.

The direct spring model approach presented here will be of use to compare the additional forces and displacements which may occur due to the effect of different support settlement conditions. From the point of view of accuracy this project gives a better analytical solution leading to more realistic calculations compared to the conventional approaches like moment- distribution, slope deflection etc. For higher degrees of freedom, more chances of mistake may occur in conventional methods.

The computer programme to analyse frame structures presented in this work proves to be a time saving and easy system. Once the data with different settlements and stiffnesses are entered, the computer will give, within seconds, the displacements and forces. It is hoped the Fortran - 77 compuer program, presented here for analysis of frame structures, could be useful for future researchers & structural engineers.

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DEFINITION OF SYMBOLS

SYMBOL	DEFINITION
α	EI/L^3
β	AL^2/I
γ	AE/L
ϵ	normal strain
σ	normal stress
λ	Rotation matrix
Λ	Transformation matrix
ϕ	co-efficient of generalised displacements
ψ	coefficient of generalised displacement
ξ	co-ordinate transformation
A	Cross-sectional area
Ci,	Generalised displacement coefficients
D	Global element-end displacement vector
E	Young's modulus
F	Global element end force vector, or
	Internal generalised force vector
I	moment of inertia
K	Global stiffness matrix, or
	Co-efficient of aspect ratio
L	Span
M	Member code Matrix, or
	Bending moment (BM)
Ma,Mb	Concentrated moments
N	Normal force
NC	Number of joint constraints
NE	Number of elements
NI	Number of degree of indeterminancy of a model
NJ	Number of joints

SYMBOL	DEFINITION
NM	Number of internal forces
PFS	Plane Frame Structure
P(x)	Distributed transverse load
Q	Applied joint force vector
R	Generalised force
SCN	Structure Code Number
T	Axial force
V	Shear force
Va,Vb	Concentrated forces (shear)
X,Y,Z	Global coordinates
b	breath of section
C1	Cos θ
C2	Sin θ
d	local displacement vector
f	local element-end force vector
gi i=1,7	coefficients of global stiffness matrix
h	heights of section
i,j,k	summation counters
l	equivalent actions
$\bar{l}$	Actual actions
$\hat{l}$	fixed joint actions
m	elements number of degree of freedom
m(x)	distributed axial force
n	number of degrees of freedom of a system model, or number of physical beams
gk	joint displacements corresponding to the system degree of freedom
v	transverse deflection
x,y,z	local co-ordinates

CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

1.1 INTRODUCTION

Before the advent of the electronic digital computer, frame structures were analysed by the classical methods. Classical methods are treated in most of the structural analysis books. However, these methods put less emphasis on some difficulties such as support displacements, effects of temperature and prestrain, beams and plates on elastic foundations etc.

Following the appearance of the computer in academic and professional environments, the necessity for analytical tools specially directed towards its use become apparent. Consequently, a number of powerful analytical devices in some methods of analysis are available to the structural designer. These methods are well established and treated in a number of technical papers. One of these methods is the matrix displacement method.

A principal objective of this study is to provide a direct spring model approach to investigate the effects of support settlements on stress distributions of frame structures so that their effects may be made available to the designer without the need for performing complicated analysis in the design office. This approach is proposed to ease the assessment of effects of support settlements using a spring model without incuring the labour for complete geometrical changes as implied in the indirect method. A secondary objective is to revise structural properties

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such as stiffness with respect to preliminary analysis under effects of settlements. The research is concerned with situations where the arrangement and proportions of structural members and the support conditions are known. In practice, the designer must first estimate the member sizes, analyse the structure, and compare the calculated and allowable stresses and displacements. Then if the designer wishes to investigate the effects of support settlements, changes will have to be made in the assummed geometrical configurations of the structure and a complete analysis should be reperformed. It is therefore necessary to develop alternative procedures whereby the desired effects of settlements could be investigated (using the spring model.)

The need for a frame structure, which is more in urban areas, varies with places and increases with the congestion of cities. A frame structure comprises of beams and columns with infinitely stiff members and has a high degree of rigidity. Shear walls are sometimes attached to resist high lateral, vertical and even seismic loads. Stability problems can, however, arise when the structure is either imprcperly detailed or constructed or when a structural portion is subjected to abnormal loads (a high earthquake or blast) or differential support settlement.

Since frame structures are normally erected on soil, the settlement of such structures are sometimes

inevitable. Various types of settlements, each being due to various causes, can occur. Some of the causes can be quantified and estimated.

The stability and stiffness of frame structures can be affected by various factors as follows:

1. Material used in construction.
2. Method of construction of frame structures - i.e. in situ or precast.
3. The overall width of the building.
4. The number of storeys.
5. Size of elements.
6. Foundation conditions.

Under normal loads (dead, imposed, wind etc) frame structures are stable structures that exibit considerable lateral stiffness. An abnormal load (eg. a high eathquake or blast) can cause high member loads, resulting in unstable situations-eg. a load bearing element under high loads might be damaged to the extent that it becomes unable to act in the designed capacity. If the failure in the element contributes to the failure in the adjacent elements, then there is a possibility that the damage may propagate to other elements. This may result in progressive collapse.

The support settlement of frame structures are inevitable unless the foundations (supports) rest on solid rock. Apart from the increased forces due to single support settlements, undesirable effects arise when differential support settlements take place. These

settlements must therefore be kept to a minimum and must also be considered where necessary in the design of frame structures. This will prevent excessive stresses in the frame and prevent structural collapse. The amount of possible settlement depends on the ultimate design load on foundation and the soil properties. Most of the types, causes and estimation of foundation settlements have been touched upon in most of the soil mechanics works.

1.2 SCOPE OF STUDY

This dissertation therefore makes detailed study of the specific aspects of mathematical modelling as they apply to the present structural model. Chapter Two further discusses the idealisation of frame structures and formulates stiffness of discrete element model, which relates element-end displacements to element-end forces through stiffness matrices. In Chapter three, the matrix displacement method using spring model is presented and the computer is used to analyse frame structures as an assemblage of discrete interconnected elements under support settlement and stiffness variation.

In chapter four, a simulation model is discussed. This is based on the following important considerations of direct spring model approach, settlement of frame, stiffness variation and parametric studies (shape,

settlement etc.)

In chapter five, an important computational aspects pertaining to the implementation of the matrix displacement method and spring model are discussed. Though this chapter is more in the realm of computer programming, it has direct emphasis on structural engineering. Since primary responsibility for the entire analysis generally lies upon the structural engineer, he should have more than superficial knowledge of the important role the computer plays in such an analysis.

In chapter six , a detailed calculation on frame structural loadings, load-cases and combinations, satisfaction of code requirements for deflection and stress levels which are necessary to aid the frame design at both the states of ultimate and serviceability limit are presented. Further, the results of analysis and a brief discussion on results are also included.

Finally, a user's guide,verification examples, a sample input output result of parametric study, and a source listing program are provided in the appendix.

1.3 LITERATURE REVIEW

The need for research into the computer aided parametric study of frame structures under support settlement and stiffness variation is discussed here. The stages of development in structural researches of settlements are also discussed.

Recent years have seen a rapid increase in the number of multi storey frame structures being constructed for both commercial and residential purposes in urban areas. Some frame structures may be erected on soil where they can be subjected to differential settlements. For this reason, there is a need to know the behaviour of such frame structures under settlements and later to see the effects of stiffness variation. It is therefore necessary to formulate a direct spring model approach for this study which can be implemented easily on the computer.

Alayade (1983) has presented the effects of support settlement on panel buildings. A detailed review of research development into behaviour of panel structures, especially shear walls, is given in chapter two, where particular attention is paid to the researches made on the problem of differential support settlements.

Gould (1972) has presented the differential settlement of Hyperbolic Colling Towers. A model of the differential settlement of a column supported hyperbolical shell of revolution was proposed. The relationship between the settlement and stress type shell was analysed by treating the support region as a semi-infinite sheet.

Grimm (1975) has presented the design for differential settlement (movement) in brick walls. The effects of differential settlements are discussed under following titles:

- Brickwalls that self distruct,
- Expansion joint,
- Masonry wall deflection,
- Wall in flexture and shear
- Wall supporting slabs,
- Wall supported on frames,
- Wall supported on foundations.

Bishra (1980) has discussed settlement-induced forces in concrete briges. Here:

1. Analysis of differential settlement-induced forces takes into consideration the time-rate settlement of different supports and these forces are evaluated at specific points.
2. The force induction factor, $E(t)$, is derived by which the elastic solution of settlement induced forces should be multiplied to obtain viscoplastic solution.

3. The 'E(t)' is independent of the final settlement, ' D_t ', but dependent on the rate of settlement.

A survey of collapse of buildings in Nigeria is presented by Ometan (1987). The author attempts to investigate the reasons for frequent collapse of buildings especially frame structures in cities. He puts blame on incompetent professionals, government and public attitude.

CHAPTER TWO

MATHEMATICAL MODEL AND STIFFNESS MATRIX

Plane Frame Structures (PFS) pose an important routine problem to a structural engineer. The matrix displacement method offers an efficient and practical tool for the analysis of frame structures. In frame analysis, the structure is idealised as a frame of interconnected elements. The elements are assigned flexural and axial stiffnesses appropriate to the part of the structure which they represent. Matrix stiffness method is then used to calculate the vertical and horizontal displacements about y & x axes and the rotation about the z axis at the joints. Hence, the axial forces, shear forces & bending moments (BM) of the frame elements at the joints / element ends can be determined.

In this chapter, specific aspects of Frame Modelling are discussed. The modelling technique is based on the analysis of a mathematical model. As a first step in the construction of the model, generalised displacements have been selected. These define the configuration and determine the degrees of freedom of the model, Next, the three basic components of the model, the conditions of compatibility, the conditions of equilibrium and the constitutive laws, are formulated. The synthesis of these components yield the mathematical model. In addition, the concept of modelling process has been introduced and

applied to obtain the continuum models representing flexural and axial deformations.

2. Fundamentals of Mathematical Models

Structural analysis is concerned with the modelling of structural behaviour where the model is mathematical rather than physical. The objective is to assess the adequacy of a proposed design with respect to strength and stiffness by methods more economical than the physical model which is to construct and test a prototype.

A mathematical model of a structure has three distinct components that represent significant features of the structure: conditions of compatibility, conditions of equilibrium and constitutives laws. Holzer (1985) states that the conditions of compitability reflect geometric properties of a structure such as continuity of deformations of elements, assemblages of elements, and boundary constraints. The conditions of equilibrium express the balance of a structure at rest, while the constitutive laws model the behaviour of materials.

2.2 Formulation of the Model

The major structural components of a PFS is as shown in figure 2.1 a&b. The PFS modelling of these components can be accomplished with the aid of a linear beam element of combined flexure and axial deformation model as illustrated in figure 2.1 c

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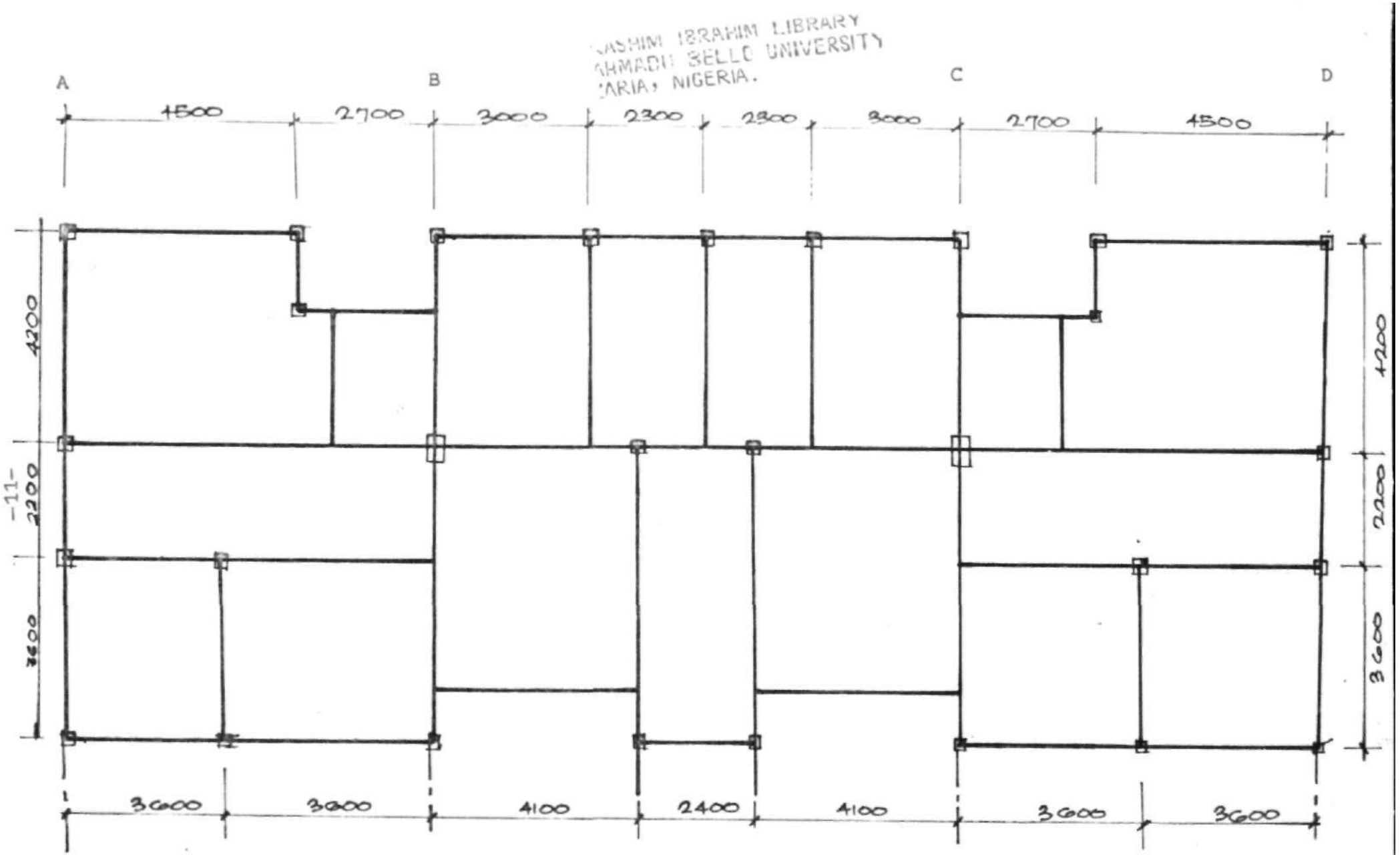
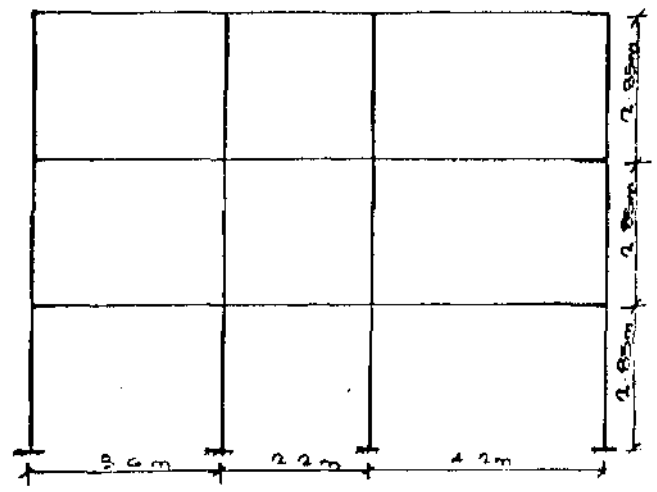
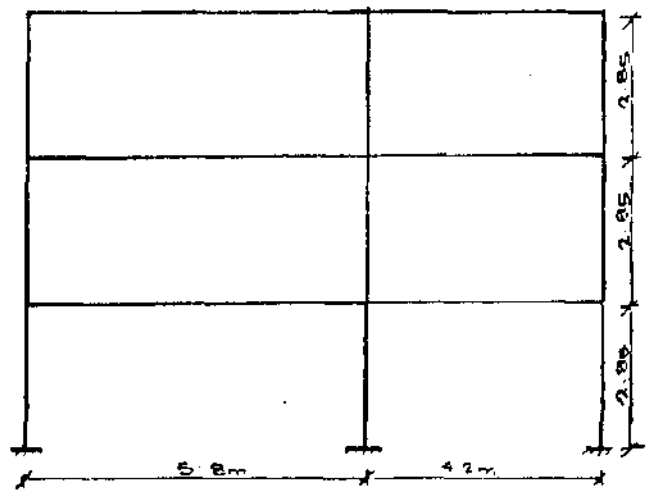


FIG.2.1: @ TWO STOREYS FLATS PLAN



SECTION AT Ⓐ / Ⓓ



SECTION AT Ⓑ / Ⓒ

FIG. 2.1B: SECTIONS

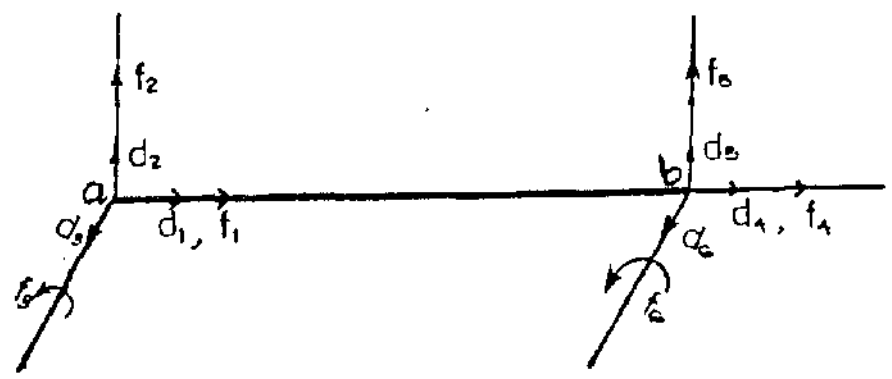


FIG.2.1C: DISCRETE ELEMENT
FLEXURAL + AXIAL

The formulation of the mathematical model centres on the selection of parameters that define the configuration of the model. Holzer (1985) states that " the configuration is characterized by the simultaneous location of all material points. The number of independent parameters required to define the structural configuration represents the degree of freedom of the model. These parameters are called the generalized displacements of the model."

In engineering analysis, the configuration of a model is generally described relative to its initial state, a reference configuration in which the model is not subjected to actions. Specifically, the configuration is defined by the displacements of each point from its initial position. This is illustrated in the following development of one dimensional elements without reference to actions that may correspond to these configurations.

2.3. Development of Continu um Models of Elements

The field of structural mechanics contain a variety of continuum models, from simple spring models to complex shell models, (Holzer 1985). Although these models may appear unrelated, they have a common basis, which is displayed in the modelling process of figure 2.2. This process defines the mathematical relations (steps 1-3) that

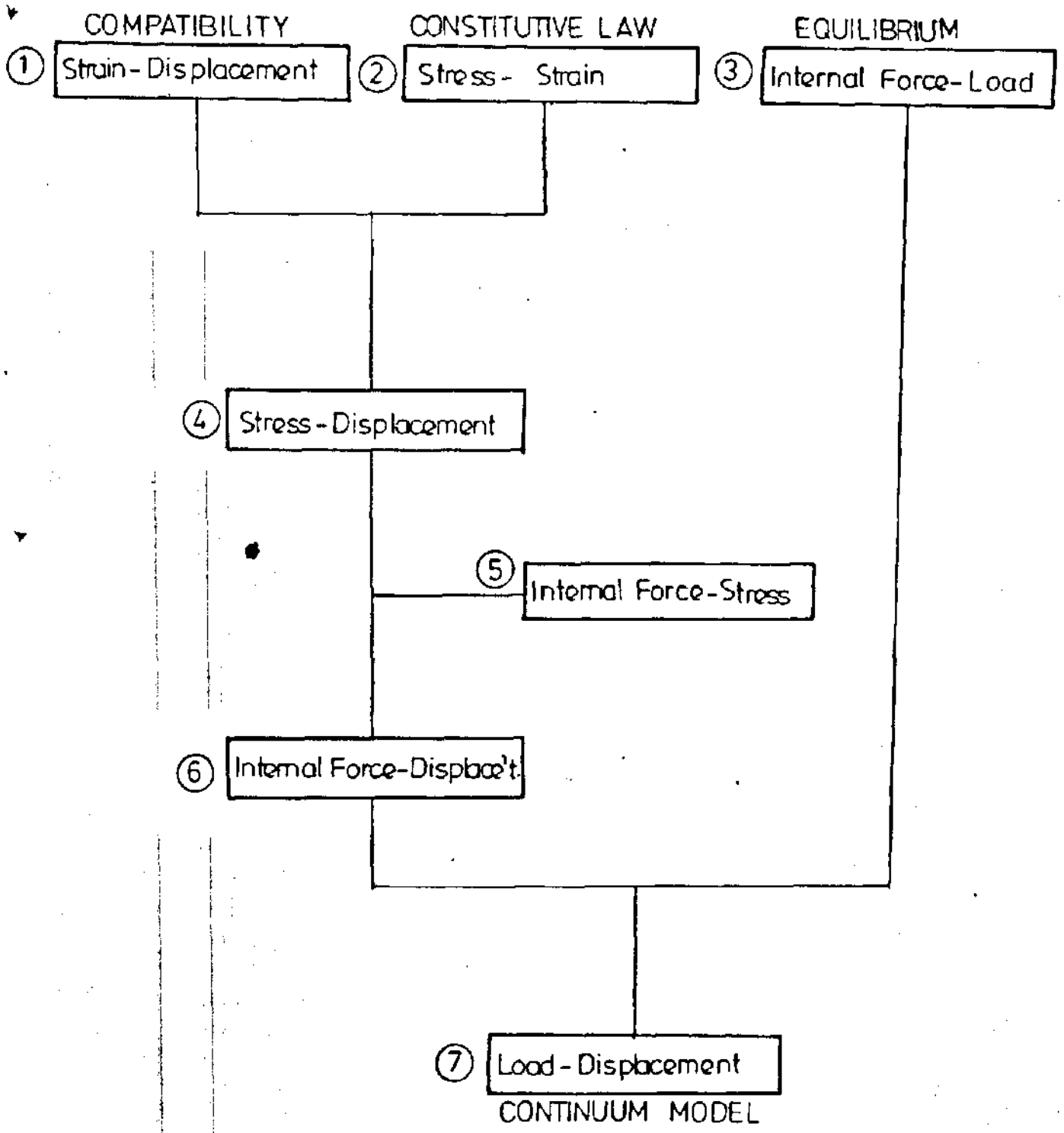


Fig. 2.2: Modelling process [Holzer(1985)]

form the components of the model and it shows how these relations may be combined to produce the continuum model. Moreover, it identifies the geometric and material limitations of linear models. Specifically, the deformations must be sufficiently small to justify linear strain - displacement relations (step 1) and the formulation of equilibrium for the undeformed state (step 3); In addition, the stresses must be sufficiently small to justify linear stress-strain relations (step 2).

The construction of continuum models according to figure 2.2. is illustrated for members experiencing flexural and axial deformations, which are the basic deformations of framed structures.

2.3.1 Flexural Deformation Model

The beam in figure 2.3 a is subjected to the distributed transverse load P (x) and the concentrated forces V_a M_a, V_b, M_b; the term force is generalized to refer to forces and moments of forces. All forces act in longitudinal plane of symmetry of the beam, which lies in the y & z - reference plane of frame. The initial configuration of the centroidal axis of the beam concides with the x-axis. The beam is prismatic, homogeneous and composed of linearly elastic material. Hence, the deformation of the beam is governed by the assumptions of the elementary beam theory. It follows that the configuration of the beam is determined by the configuration of centroidal axis.

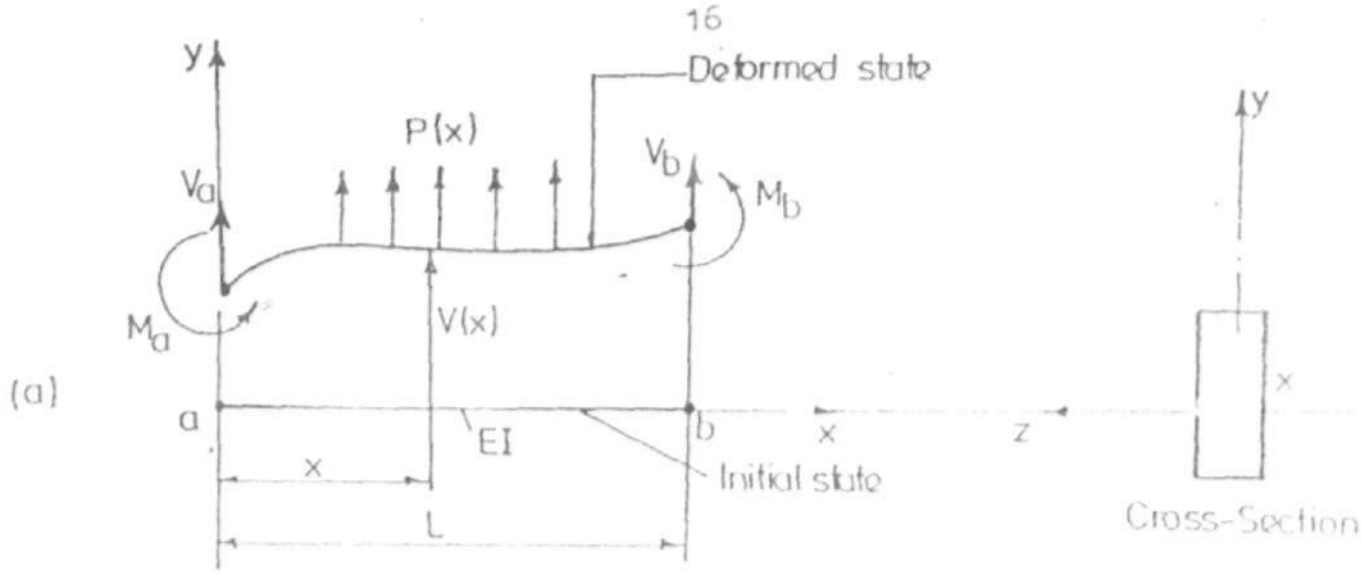


Fig 2.3: Flexural Deformation Model

The mathematical model of the beam is formulated on the basis of the flow chart in fig. 2.2.

Strain-Displacement Relation

$$\epsilon(x, y,z) = \epsilon(x,y) = - y d^2 v(x)/dx^2 \qquad (2.1)$$

ϵ is the normal strain, which is positive in tension, and v(x) defines the transverse deflection of the centroidal axis. Eq. 2.1 is only valid for infinitesimal deformations, Holzer (1985).

Stress-Strain Relation

$$6 = E\epsilon \qquad (2.2)$$

6 is the normal stress, and E is the modulus of elasticity.

Internal Force-load Relations

$$dV/dx = P, \quad dM/dx = V \qquad (2.3a)$$

or

$$d^2M/dx^2 = P. \qquad (2.3b)$$

V is the shear force and M is the bending moment. The positive sense of the external and internal forces of eqs. 2.3 is shown in figure 2.3b.

Stress-Displacement Relation

Eqs. 2.1 and 2.2 yield

$$6 = - Ed^2v/d^2y \qquad (2.4)$$

Internal Force - Stress Relations

figure 2.3c indicates that

$$N = \iint_A 6 \, dA = 0 \qquad (2.5a)$$

and

$$M = -\iint_A 6 \, dA y \qquad (2.5b)$$

Internal Force-Displacement Relations

Eqs. 2.4 & 2.5 yield

$$N = -Ed^2 v/dx^2 \int_A ydA = 0 \qquad (2.6a)$$

and

$$M = Ed^2 v/dx^2 \iint_A y^2 dA = EId^2 v/dx^2 \qquad (2.6b)$$

I is the moment of inertia of the cross sectional area with respect to the controidal axis. It follows from Eq. 2.6a that

$$\iint_A ydA = o \qquad (2.7)$$

which verifies that the neutral axis passes through the centroidal axis.

Load-Displacement Relation

The substitution of Eq. 2.6b into Eq. 2.3b yields the continuum model of a prismatic, homogeneous, elastic beam.

$$EId^4 v/dx^4 = P \qquad (2.8)$$

Observe that the configulations of the centroidal axis of the beam, which is defined by v(x) determines any desired measure of response reflected by the model of the beam, for example, from Eqs. 2.6b, 2.3b and 2.4 we obtain

$$M(x) = EId^2v(x)/dx^2 \qquad (2.9a)$$

$$V(x) = EId^3v(x)/dx^3 \qquad (2.9b)$$

$$6(x,y) = - M(x)\, y/I \qquad (2.9c)$$

Note that when there are no applied forces, the model is defined by the homogenous differential equation,

$$d^4v/dx^4 = 0 \qquad (2.10)$$

2.3.2 Axial Deformation Mathematical Model

The rectangular beam shown in fig. 2.4a is subjected to the distributed axial force m(x) and the end axial force Ta & Tb. The lines of action of all axial force are collinear with the centroidal axis of the beam. The sense of a force is determined by right hand rule. The deformations of the beam are governed by the following assumptions(Holzer, 1985): (1) The centroidal axis remains straight, and(2) all longitudes of cross section remain straight and displace through the same amount about the centroidal axis.

The formulation of the mathematical model is based on the flow chart in fig. 2.2.

Strain -Displacement Relations: $\epsilon(x,y) = Y \frac{dw}{dx}$ (2.11)

where $\epsilon(x,y)$ is the axial strain at any point (x,y) of the cross section, and wx is displacement of cross-section.

Stress-Strain Relation: It follows the Hooks law, $6_a = E\epsilon$

where 6a = axial stress . (2.12)

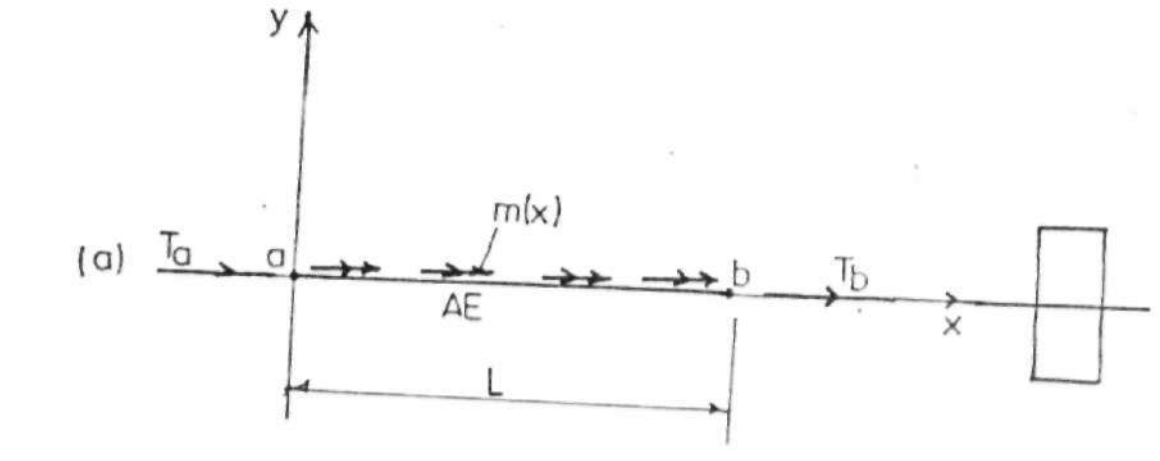


FIG. 2.4 Axial Deformation Model

Internal Force-load Relation: $dT/dx = -m$ (2.13)

Stress-Displacement Relation: Eqs. (2.11)&(2.12) yield

$$6a = E_o\ y\ dw/dx \qquad (2.14)$$

Internal Force-stress Relation

fig. 2.4 indicates that $T = \int_A 6a\ dx$ (2.15)

Internal Force-Displacement Relation

eqs. (2.14) & (2.15) yields $T = \int_A (E\frac{dw}{dx}).\ y\ dx.$

$$= EA\ \frac{dw}{dx} \qquad (2.16)$$

A = cross sectional Area of beam.

Load-Displacement Relations

Combining eqs 2.13 & 2.16, we obtain the continuum model of a beam subjected to a distributed axial stress:

$$AE\ \frac{d^2w}{dx^2} = -\ m\ \ldots\ldots \qquad (2.17)$$

Observe that when there is no applied distributed axial force, eq. 2.17 reduces to homogeneous differential equation:

$$\frac{d^2w}{dx^2} = 0\ \ldots\ldots \qquad (2.18)$$

2.3.3 SPRING MODEL

Springs play an important role in foundation settlement problems. If the deflection is known then a spring can be inserted in the area of concern. The spring's stiffness

should be no more than two orders of magnitude stiffer than the maximum member axial stiffness (AE/L).

The problem is approximated by applying a force in the direction of the spring so as to produce the known deflection. To understand this fundamental let us take a simple frame example as shown in figure 2.5.
A 50 mm vertical displacement is required at joint No. 4. The maximum member stiffness $AE/L * 10 = 460350$ KN/m is used as the vertical spring stiffness at joint number 4. A vertical force of - 23017.5 KN is applied at a joint number 4 to force a 50 mm vertical displacement.

Thus: $Qs = Ksq$.....(2.19)

Where Ks = stiffness of the spring.

2.4 Derivation of stiffness matrix of discrete mathematical model

In the absence of interior loads, the continuum models (section 2.3.) become homogenous differential equations of order n, whose solutions contain n arbitrary constants. Since the solutions define element configurations, the constants represent n generalised displacements. Accordingly, the flexural and axial continuum models can be reduced exactly to discrete models.

This reduction is carried out in the following way: first, the element configurations are expressed in terms of the element - end displacements by imposing geometrical

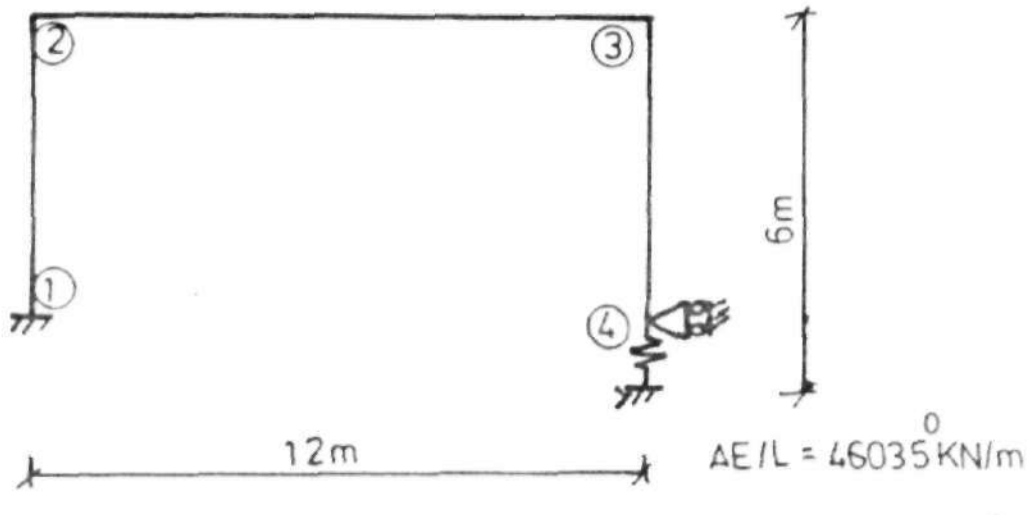


FIG. 2.5 Spring Model

boundary conditions on the solutions of the homogenous differential equations. Then, the element - end forces are related to the element end -displacement relations of the continuum models (step 6 of figure 2.2). The resulting set of algebraic equations form the basic element models used in displacement method for analysis of frame structures.

2.4.1 Flexural deformation model Stiffness

Figure 2.6 depicts a beam under the action of end forces but without interior loads. To formulate relations between the end forces and the corresponding end displacements, we start with the homogenous differential equation.

$$dv^4/dx^4 = 0 \qquad (2.21)$$

which is obtained from equation(2.8) by setting P = 0.
The geometric boundary conditions are

$$v(0) = v_a, \quad dv(0)/dx = \theta_a$$
$$v(1) = v_b, \quad dv(L)/dx = \theta_b \qquad (2.22)$$

Eq(2.21) has the solution,

$$v = C_0 + C_1 x + C_2 x^2 + C_3 x^3 \qquad (2.23)$$

by definition, the co-efficients of eq. 2.23 represents generalized displacements and the element has three degrees of freedom. The reasons for introducing equation 2.23 were given by Holzer (1985) as: (1) it satisfies the homogenous differential equation of a beam: hence equation

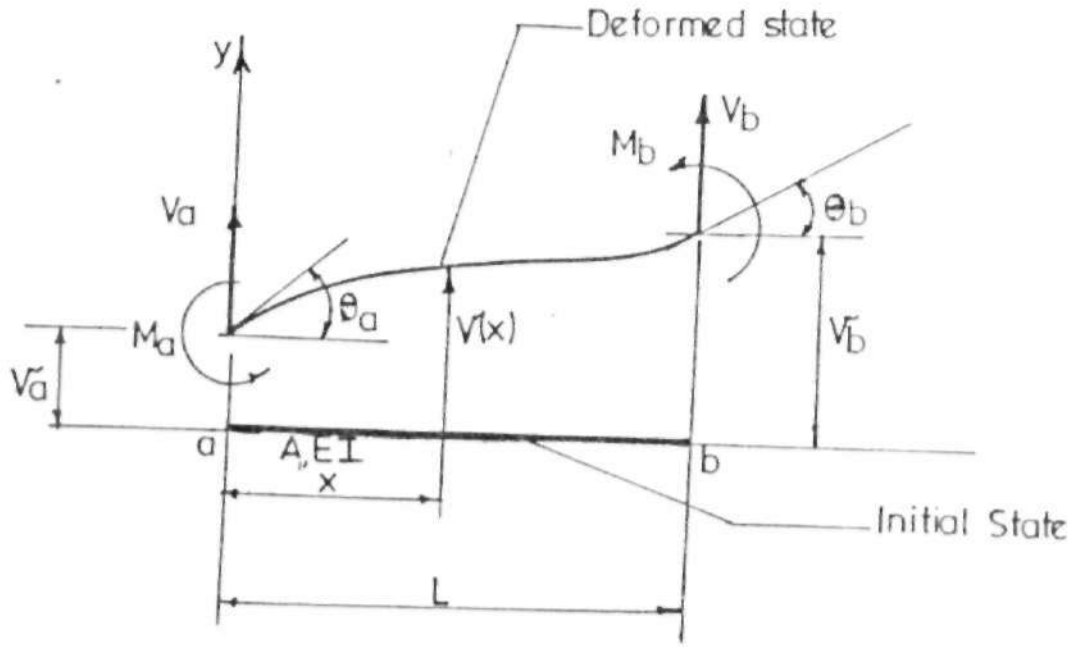


Fig 2.6 : Flexural Deformation Model stffness

2.23 characterises the configurations of the beams subjected to boundary actions.

(2) polynomials form basic building blocks of many interpretation functions - also used in the finite element method.

Selecting the element - end displacements, v_a, θ_a, v_b θ_b, as generalised displacements and expressing the configuration in terms of them can be accomplished by imposing the boundary conditions (eq. 2.22) on eq. 2.23 which yields the set of algebraic equations:

$$\begin{aligned} C_0 &= v_a \\ C_1 &= \theta_a \\ C0 + LC1 + L^2\,C2 + L^3\,C3 &= v_b \\ C1 + 2LC2 + 3LC3 &= \theta_b \end{aligned} \qquad (2.24)$$

whose solution is:

$$\begin{aligned} C_o &= v_a \\ C_1 &= \theta_a \\ C_2 &= 1/L^2\,(-3v_a - 2L\theta_a + 3v_b - L\theta_b) \\ C_3 &= 1/L^3\,(2v_a + L\theta_a - 2v_b + L\theta_b) \end{aligned} \qquad (2.25)$$

Substituting eqs. 2.25 into eq. 2.23 and collecting terms of like displacements, the configuration of the beam can be expressed in the form.

$$v = \phi_a v_a + \psi_a \theta_a + \phi_b v_b + \psi_b \theta_b \qquad (2.26)$$

where

$$\theta_a = 1 - 3\xi^2 + 2\xi^3$$

$$\psi_a = (\xi - 2\xi^2 + \xi^3)L \qquad (2.27)$$

$$\phi_b = 3\xi^2 - 2\xi^3$$

$$\psi_b = (-\xi^2 + \xi^3)L$$

and

$$\psi = x/L, \quad 0 <= \xi <= 1 \qquad (2.28)$$

The co-ordinate transformation is Eq 2.28 was introduced to simplify the solution, it results in the following transformation of derivatives as given by Holzer (1985).

$$d^n v/d\psi^n = (1/L)^n \, d^n v/d\xi^n; \quad n=1,2,3.. \qquad (2.29)$$

with the aid of Eqs...2.9, 2.26 and 2.29, the bending moment and shear force can be expressed as

$$M(\xi) = EI/L^2 \quad (\phi_a'' v_a + \psi_a'' \theta_a + \phi_b'' v_b + \psi_b'' \theta_b)$$

$$V(\xi) = EI/L^3 \quad (\phi_a''' v_a + \psi_a''' \theta_a + \phi_b''' v_b + \psi_b''' \theta_b) \qquad (2.30)$$

where

$$\phi_a'' = -6 + 12\xi \quad , \quad \phi_a''' = 12$$

$$\psi_a'' = (-4+6\xi)L \quad , \quad \psi_a''' = 6L$$

$$d\phi'' = 6 - 12\xi, \quad \theta_b''' = -12 \qquad (2.31)$$

$$\psi_b'' = (-2+6\cdot\xi)L, \quad \psi_b''' = 6L,$$

On the basis of the beam sign convention of figure 2.3b, the end forces of the beam in figure 2.4 are defined as

$$Ma = -M(0), \quad Va = v(0)$$
$$Mb = M(1); \quad Vb = V(1) \qquad (2.32)$$

The evaluation of equation 2.30 and 2.31 according to eq. 2.32 results in the force displacement relations.

$$Va = \alpha C\ (12v_a + 6L\theta a - 12vb + 6L\theta B)$$
$$Ma = \alpha C\ (6Lva + 4L^2\theta a - 6Lvb + 2L^2\theta b)$$
$$Vb = \alpha C\ (-12va - 6L\theta a + 12vb + 6L\theta b)$$
$$Mb = \alpha C\ (6Lv_a + 2L^2\theta a - 6Lvb + 4L^2\theta b) \qquad (2.33)$$

2.4.2 Axial Deformation Model Stiffness

Consider the bar in fig. 2.7, subjected to end axial forces Ta, and Tb. We seek to establish relations between the end axial forces and corresponding end displacements wa and wb.

Without interior load the differential equation of the bar in eq. 2.18 becomes

$$d^2w/dx^2 = 0 \qquad (2.35)$$

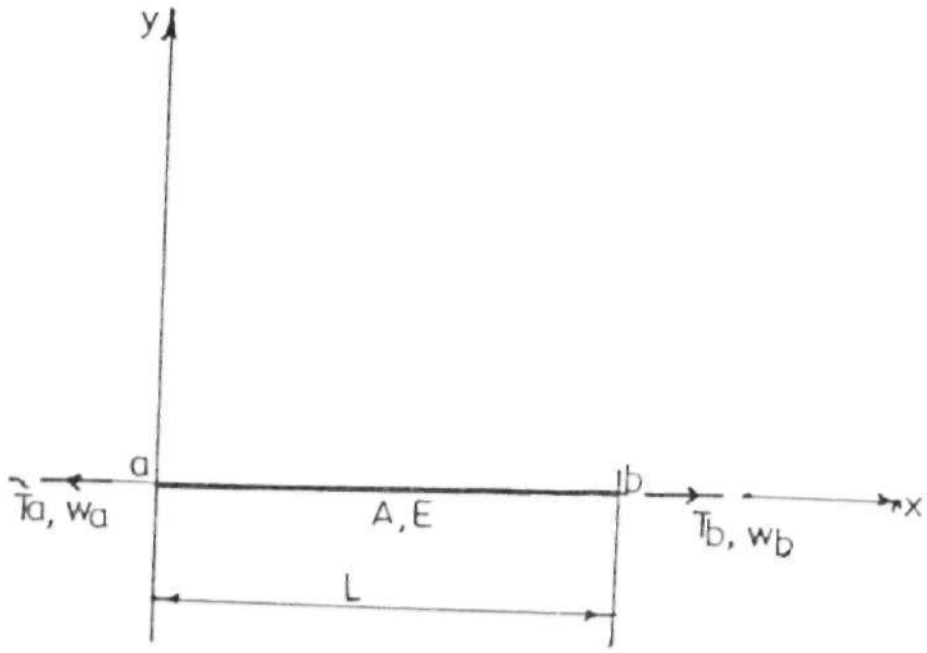


Fig. 2.7 : Axial Deformation Model stiffness

The geometric boundary conditions are $w(0) = w_a$

$$w(L) = w_b \quad (2.36)$$

The solution of eq. 2.35, $w = C_0 + C_1 X$, can be specialised by geometric boundary conditions this gives:

$$C_o = w_a$$

$$C_1 = 1/L \quad (w_b - w_a) \quad (2.37)$$

and hence, $w = w_a + x/L \quad (w_b - w_a)$ (2.38)

We know, $T(x) = EA \frac{dw}{dx}$

$$\therefore \quad Tx = AE/L \quad (w_b - w_a) \quad (2.39)$$

The evaluation of equation 2.39 at x = 0 and L consistent with the sign convention in fig. 2.4, that is Ta = - T(o) and Tb = T(1) yields the desired force displacement relations.

$$Ta = AE/L \quad (w_a - w_b)$$

$$Tb = AE/L \quad (-w_a + w_b) \quad (2.40)$$

2.4.3 Stiffness of combined Axial and Flexural Model

In preparation for matrix methods of analysis, the discrete element models (section 2.3) are now expressed in matrix form. Matrix notation permits one to unity distinct structural elements in a mathematical form that reveals their common characteristics.

In matrix notation, the conventional x, y & z, designations of the element co-ordinate axes shown in figures 2.3 (FDM) and 2.4 (ADM) are replaced by the integers 1,2&3. Thus, the 1 - axis, which is directed from the a-end to the b-end of the element, concides with the centroidal axis of the element and the 2 and 3 axes correspond to principal axes of the cross-section fig. 2.8. Since this co-ordinate system is intrinsic to the geometry of the element, it is called the local coordinate system or the local frame of reference.

The element - end displacements and forces, denoted di and fi, are numbered in the sequence of the coordinate axes from the a - end to the b - end of the element, i = 1,2,3,.....m; where m is the number of degree of freedom of the element. This is, illustrated in fig. 2.9 a and b for elements with axial and flexural deformations, respectively and in fig 2.8 and 2.9c for element with both axial and flexural deformations. Moreover, to regard the element end displacements and forces as coordinates, a local reference frame is assigned to each end of element (fig. 2.8). This provides a simple sign convention. A displacement or force is positive in the direction of coordinate axis. The positive sense of a rotation or moment about the 3 - axis is determined by the right hand rule: hence, the positive sense is counter clockwise in the 1,2 - plane, the plane of the element.

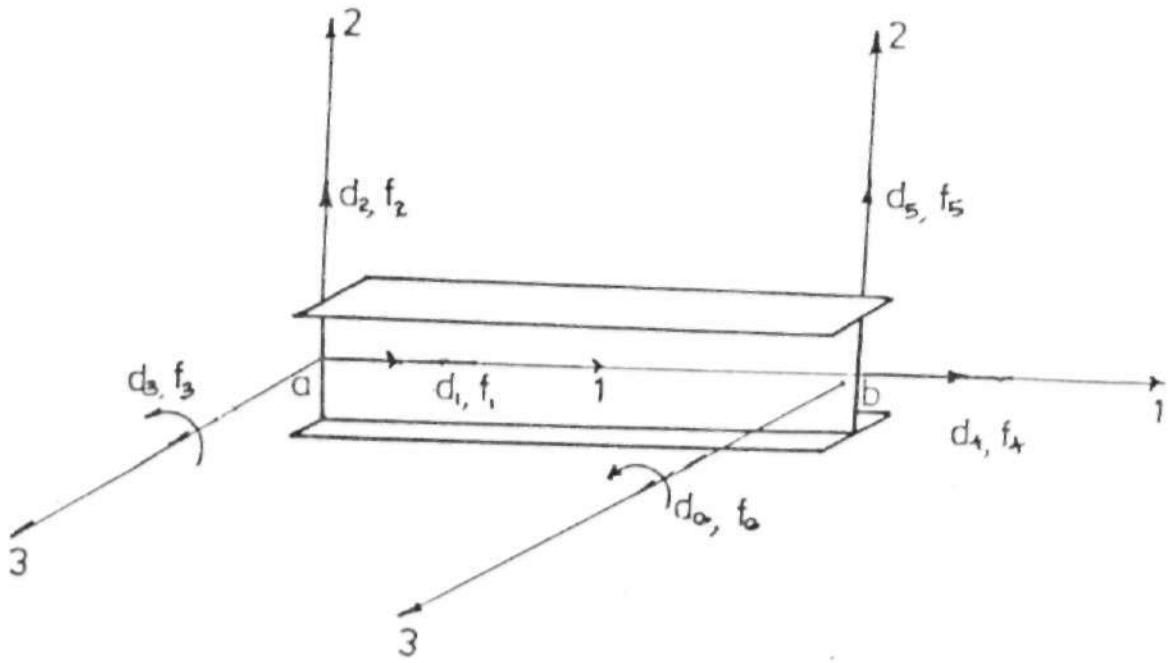


Fig 2 .8. Axial + Flexural Deformation Model stiffness

According to these conventions, the elements in fig 2.6 (F D M) and 2.7 (ADM) are represented as shown in fig. 2.9a and b and their models are expressed as:

$$fi = \sum_{I=1}^{M} kij\ dj\ ;\ i = 1,2,.....m \quad (2.45)$$

or

$$f = kd \quad (2.46)$$

where kij is stiffness coefficient by Eq 2.46. kij has units of force/displacement. **k** is the stiffness matrix, d is the displacement vector, and f the force vector.

Flexural Deformation Model

From fig. 2.9b, the substitutions

$$d_1 = {}^{v}a,\ d_2 = \theta a,\ d_3 = {}^{v}b,\ d_4 = \theta b \quad (2.47)$$

and

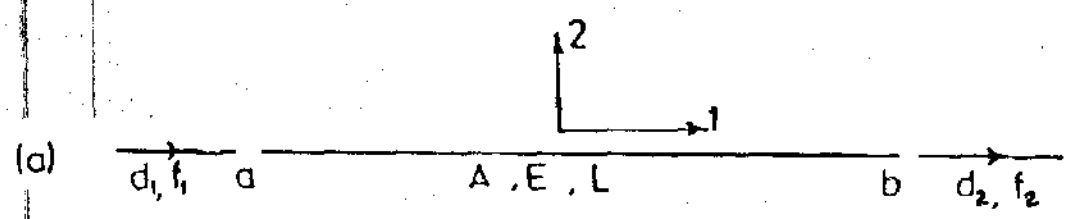
$$f1 = Va,\ f2 = Ma,\ f3 = Vb,\ f4 = Mb$$

transform Eqs. 2.33 into

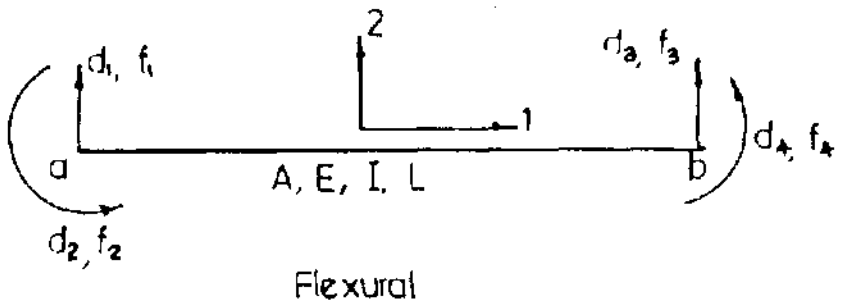
$$\begin{aligned} f_1 &= \alpha\ (12d1 + 6Ld2 - 12d3 + 6Ld4) \\ f_2 &= \alpha\ (6Ld1 + 4L^2d2 - 6Ld3 + 2L^2d4) \\ f_3 &= \alpha\ (12d1 - 6Ld2 + 12ds - 6Ld4) \\ f_4 &= \alpha\ (6Ld1 + 2L^2d2 - 6Ld3 + 4L^2d4) \end{aligned} \quad (2.48)$$

or

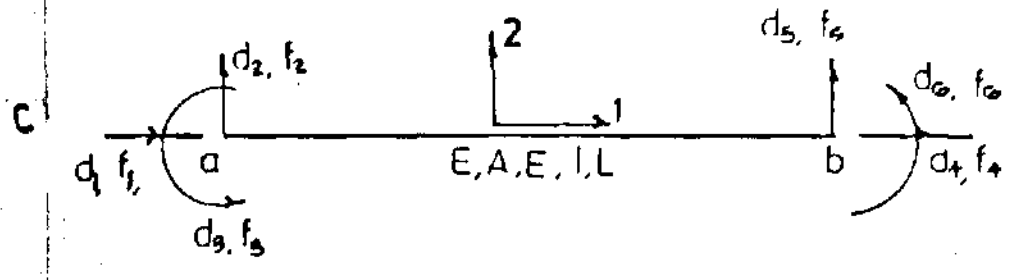
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Axial



Flexural



Axial + Flexural

Fig. 2.9: Deformation Models

$$\begin{bmatrix} f_1 \\ f_2 \\ f_3 \\ f_4 \end{bmatrix} = \alpha \left[\begin{array}{cc|cc} 12 & 6L & -12 & 6L \\ 6L & 4L^2 & -6L & 2L^2 \\ \hline -12 & -6L & 12 & -6L \\ 6L & 2L^2 & -6L & 4L^2 \end{array}\right] \begin{bmatrix} d_1 \\ d_2 \\ d_3 \\ d_4 \end{bmatrix}$$

where

$$\alpha = EI/L^3$$

AXIAL DEFORMATION MODEL

From fig. 2.9a, the substitution $\gamma = AE/L$

and

$d1 = wa$, $d2 = wb$

$f1 = Ta$, $f2 = Tb$ (2.49)

Transform Eq. 2.40 into

$$f1 = \gamma (d1 - d2)$$

$$f2 = \gamma (-d1 + d2) \quad (2.50a)$$

or

$$\begin{bmatrix} f_1 \\ f_2 \end{bmatrix} = \gamma \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} \begin{bmatrix} d_1 \\ d_2 \end{bmatrix} \quad (2.50b)$$

where $\gamma = AE/L$

AXIAL + FLEXURAL DEFORMATION MODEL

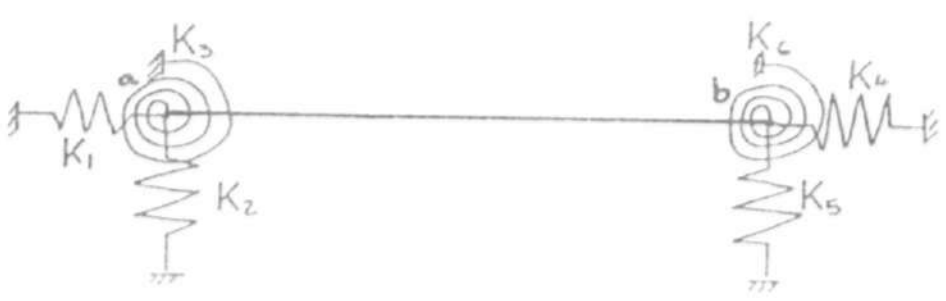
When these two deformations occur simultaneously as in a frame, it is necessary to combine them into a single element. To superimpose the models of the elements in fig. 2.9a, b to obtain the model of element in fig 2.9c, we

introduce the following change in subscripts. The subscript 2 in eq. 2.50 is replaced by the subscript 4, and the subscripts 1,2,3,4 in eq. 2.48 are replaced by subscripts 2,3,5,6, respectively. This yields the combined element model.

$$\begin{bmatrix} f1 \\ f2 \\ f3 \\ \\ f4 \\ f5 \\ f6 \end{bmatrix} = \alpha \left[\begin{array}{ccc|ccc} \beta & 0 & 0 & -\beta & 0 & 0 \\ 0 & 12 & 6L & 0 & -12L & 6L \\ 0 & 6L & 4L^2 & 0 & -6L & 2L^2 \\ \hline -\beta & 0 & 0 & \beta & 0 & 0 \\ 0 & -12 & -6L & 0 & 12 & -6L \\ 0 & 6L & 2L^2 & 0 & -6L & 4L^2 \end{array}\right] \begin{bmatrix} d1 \\ d2 \\ d3 \\ \\ d4 \\ d5 \\ d6 \end{bmatrix} \qquad (2.51)$$

2.5 Derivation of Stiffness Matrix of Spring Model

In the support settlement problem, the assumed spring model has a direct effect on the system stiffness matrix model at a particular support and direction. The derivation of the stiffness matrix in such case is simple. By observation, the global stiffness matrix for spring model will be of the following form:


K3
a
K1
K2
Kc
b
K4
K5

$$K_s = \left[\begin{array}{ccc|ccc} K1 & 0 & 0 & & & \\ 0 & K2 & 0 & & 0 & \\ 0 & 0 & K3 & & & \\ \hline & & & K4 & 0 & \theta \\ & 0 & & 0 & K5 & 0 \\ & & & 0 & 0 & k6 \end{array}\right] \qquad (2.52)$$

Where the subscripts 1,2,.....6, imply the same meaning as in the eq. 2.51

And K1 = AE/L similarly K4 = AE/L

K2 = AE/L K5 = AE/L (2.53)

K3 = 3EI/L K6 = 3EI/L

where

K3 & K6 are Rotational Stiffnesses.

The system model for spring is now obtained as follows:

$Q_s = K_s q$ which can be

superimposed on $Q = Kq$

And hence

$$Kq + K_s q = Q + Q_s. \qquad (2.54)$$

Where K is defined in eq. 3.20

K_s is defined in eq. 2.52

Q is equivalent force vector

Q_s is spring force vector

CHAPTER THREE

FUNDAMENTALS OF MATRIX DISPLACEMENT METHOD

3.1 Introduction

A general approach to the matrix displacement method is presented in a form, which makes it suitable for computer analysis of frame structures represented as an assemblage of discrete elements. Specifically the chapter develops and reviews the foundation for the matrix displacement method as applied to frame structures under support settlement. Conventions are introduced to represent frame structures in a form suitable for computer analysis. Next, the degrees of freedom are enumerated, conditions of compatibility and equilibrium are formulated without references to a visual image of the structure and coordinate transformation, required in the assembly process, is presented. Finally an efficient procedure is formulated for the assembly of element models into the system model and element actions are incorporated in section 3.9.

3.2 Notation and Convention:

In order to analyse a frame structure in a form suitable for computer analysis, it is convenient to image the frame structure as composed of joints and elements.

A joint is a point to which at least one element is incident. It is used to connect one element to another, while an element is a structural component represented by a straight line connecting two joints. A joint is placed at each element and several elements have a common joint. For a typical modelled frame structure see fig. 3.1.

3.2.1 Frame Structure Geometry

The location and orientation of the global frame of reference is arbitrary; However, the structure is assumed to lie in the 1 & 2 global coordinate plane. The global coordinate axes are represented by dashed lines to differentiate them from the solid local coordinate axes (fig. 3.2). The positive element (local) 1 - axis is located from the lower joint number to the greater joint number. The positive 2 - axis is located 90 degrees counter clockwise to the element positive 1 - axis. Both the global and local 3 - axes are chosen to make the plane of reference right-handed.

3.2.2 Joint Co-Ordinate Axes

Each joint must be properly located with respect to the global system. For most frame structures problems, it is convenient, but not necessary, to orient the positive 2 - axis such that it runs parallel but opposite to the direction of gravity. The positive 1 - axis is then located by drawing a line 90 degrees clockwise with respect to the positive 2 - axis (see fig. 3.3) and finally the positive 3- axis is chosen to make the global frame of reference

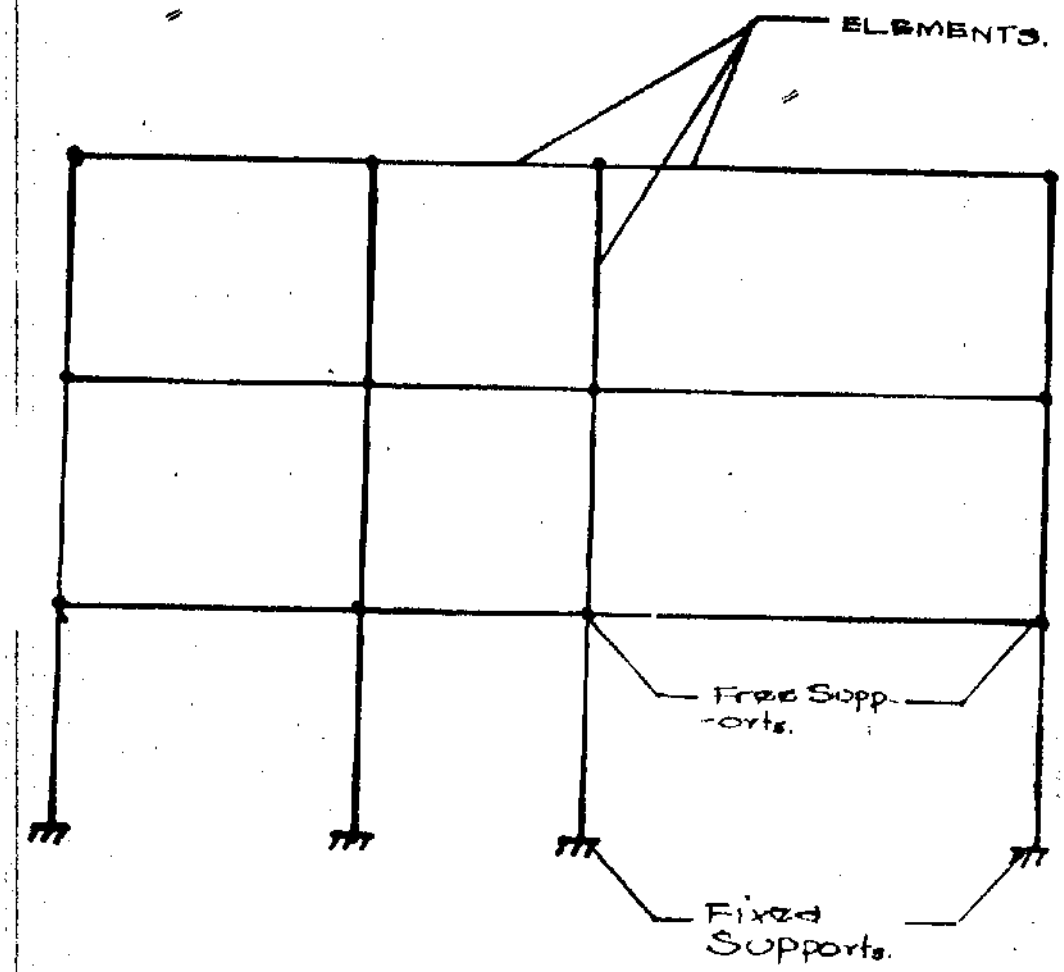


FIG. 3.1 TYPICAL MODEL OF A FRAME STRUCTURE

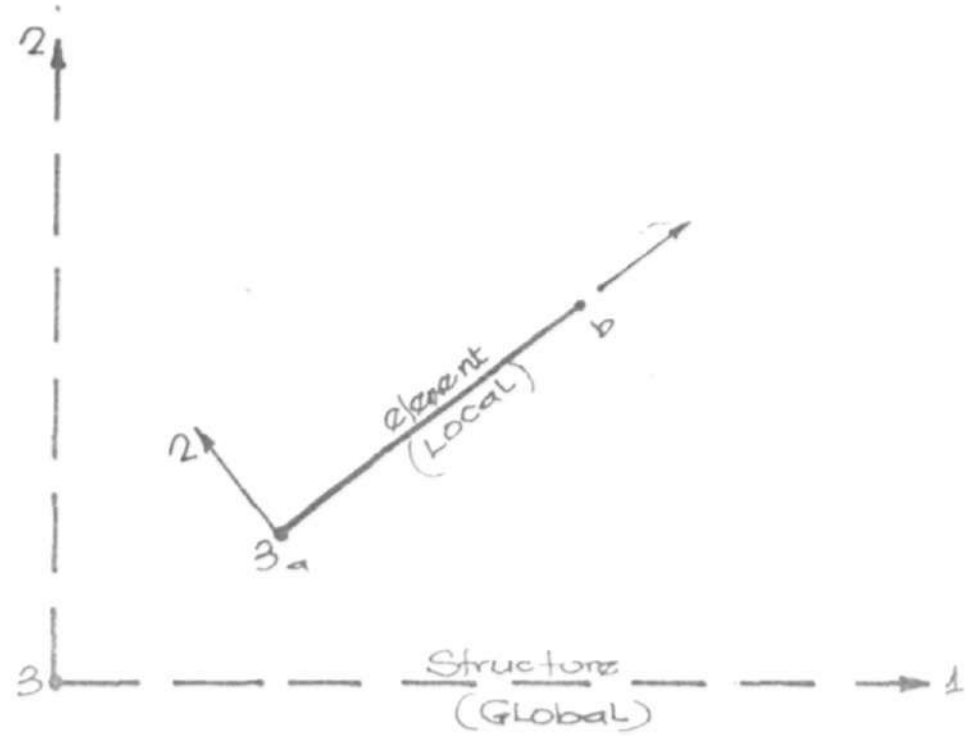


FIG 3.2 CO-ORDINATE SYSTEM

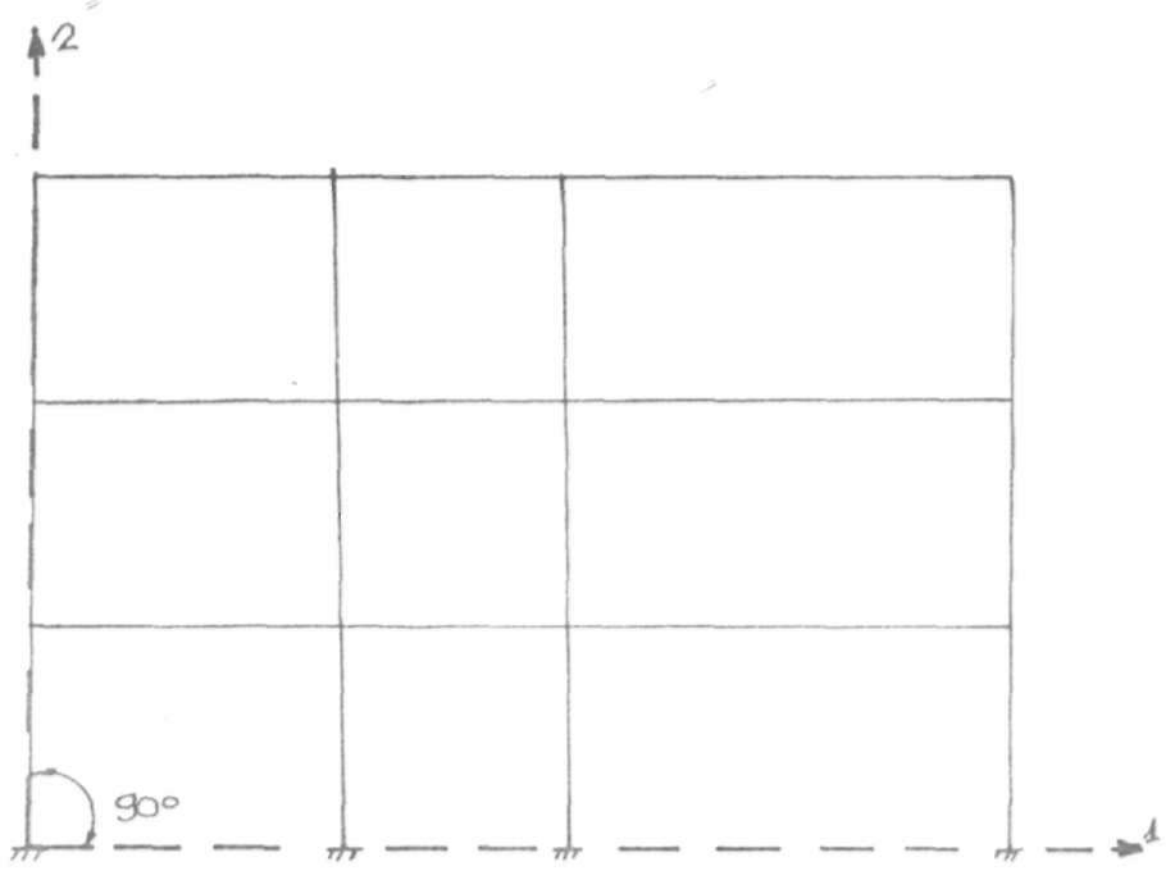


FIG. 3.3: SUGGESTED ORIENTATION OF
GLOBAL COORDINATES A FRAME

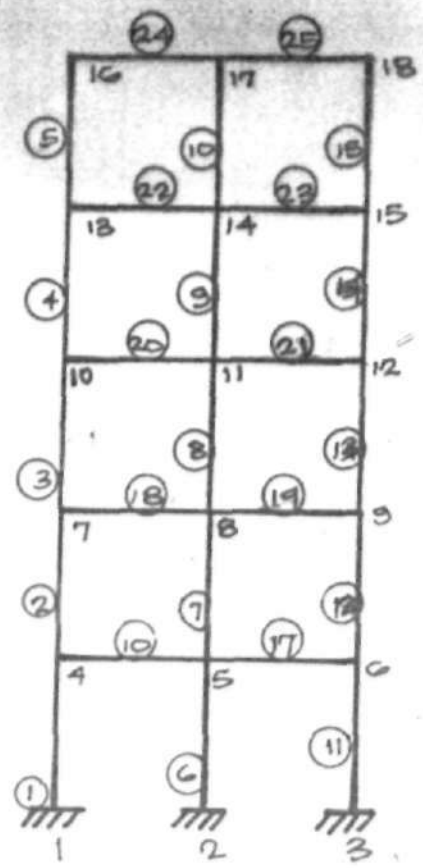
right -handed. The reason for this particular selection of co-ordinate orientation will become more apparent when entering joint loads data (Appendix 1). Finally the joint coordinates are given by the 1,2 axes similar to conventional x,y - axes.

3.2.3 Joint Numbering

Each joint must be numbered for identification. It is necessary to number the joint in a particular sequence. Random numbering is allowed but will require that a large amount of computer memory (Random Access Memory RAM) devoted to store the structural stiffness matrix. This will required a longer analysis routine and decrease the maximum size of structure that can be analysed.

To decrease the stiffness matrix storage requirement (hence decrease the analysis run time) an optional numbering scheme can be employed. Joint numbering optimization is achieved when the maximum numerical difference of all the element joint pairs are minimised. Example of joint numbering is shown in figure 3.4.

The best joint numbering scheme for minimum half bandwidth is to have adjacent joint numbers as closely together as possible. Often structures are predominately longer in one direction. Such structures have inherently small half - bandwidth if numbered along the shorter direction. **(Abubakar, 1987)**



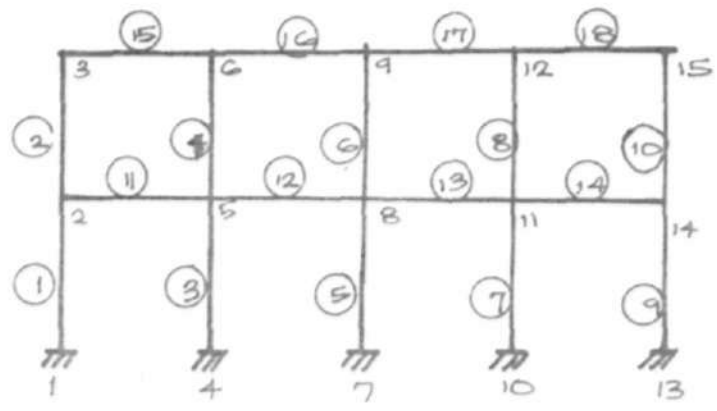


FIG. 3.4: JOINT NUMBERING SCHEME AND ELEMENT CONNECTIVITY

3.2.4 Element Connectivity

An element is connected to its joint pairs. The local 1- axis is directed from the lower to the higher number joint to which the element is incident. The numerically smaller joint number is termed as 'a-end' while the numerically higher joint is termed as 'b-end '. Connectivity is achieved by drawing an arrow to each element pointing to the higher numbered joint to which the element is incident. See figure 3.4.

3.2.5 Element Numbering

Each element must be numbered for identification. Elements can be numbered at random. No time or storage space is saved by special numbering schemes. However, element can be numbered in such way as to facilitate data input and easy to understand output of analysis. See figure 3.4 .

3.2.6 Spring Data Input

Spring data: Spring data involves data concerning horizontal, vertical or rotational springs used in structured frame (see Appendix-I for spring coding). If there are no springs in the frame this data is bypassed. The springs should only act at joints and their direction and value are always positive. The number of rows of data that are ready to receive input are generated by the initialising data; no. of springs, spring stiffness(s) at a joint etc

3.3 Generalise Displacements

By definition (section 2.3), generalised displacements are independent parameters required to define the configuration of a model. The number of generalised displacement is equal to the number of degrees of freedom of the model. If the discrete element models of chapter 2 are assembled into frame structure, the resulting system model is also discrete; that is, it has a finite number of degrees of freedom, Holzer (1985),

$$n = l * NJ - Nct \qquad (3.1)$$

where,

l = degrees - of - freedom of a free joint

(= 3 for frame structures)

NJ = number of joints.

Nct = number of joints constraint.

Eq 3.1 follows from conditions of compatibility, which are boundary conditions, expressed as joint constraints, and continuity conditions between element and joint displacements. If an element has l degrees of freedom at each end, a free joint at an assemblage composed of these elements has l degree of freedom. Thus, the number of degrees of freedom of the assemblage is equal to l times the number of joints minus the number of joint constraints.

Each element require 3 independent unknown internal forces (Wang 1983), thus working the degrees of indeterminancy of the model

$$NI = 3 \cdot NM - n \qquad (3.2)$$

Since the discrete element models do not represent element actions, assemblages of these elements can only represent joint actions such as joint loads and prescribed joint displacements. Element actions will be incorporated in section 3.8.

3.4 Components of the Model

A mathematical model of a structure is composed of conditions of compatibility, conditions of equilibrium, and constitutive laws (Section 2.2). The constitutive laws, representing material behaviour, are inherent in the element models. Hence to assemble element models into a system model, only the conditions of compatibility and equilibrium need to be formulated.

For the automatic computer assembly of element models, the conditions of compatibility and equilibrium will be formulated by the code number technique which was introduced by Tezcan (1963).

3.4.1 Compatibility

The conditions of compatibility can be expressed in compact form by the member code matrix, M, which is defined as in Holzer (1985):

$$M = (Mij) \qquad (3.3)$$

(NE, m)

where

$$Mij = \begin{cases} K \text{ if } Dj = qk;\ k = 1,2,....n \\ \\ '0' \text{ otherwise} \end{cases}$$

qk = joint displacement corresponding to the system degree of freedom, k.

Dj^i = Element - end displacement referred to global coordinate axes.

Thus the i-th row of M corresponds to the ith element, the jth column of M corresponds to the jth element displacement and the entry in the location defined by the ith row and jth column of M is k if the element displacement Dj^i corresponds to any joint displacement qk. Otherwise it is zero.

The significance of the member code matrix is that once it is defined, no visual reference to the structure is required to formulate conditions of compatibility or equilibrium for the assemblage specifically, the displacement vector of the ith element can be defined by the following transformation.

DISPLACEMENT TRANSFORMATION $q \xrightarrow{M} D^i$

1. Match the row of D^i with the entries of the ith row of M.
2. Assign the values qk to each component of D^i that corresponds to a positive integer k.
3. Assign the value zero to each component of D^i that corresponds to a zero integer.

3.4.2 Equilibrium

Any configuration of a system for which all generalised forces vanish is an equilibrium configuration (Holzer 1985). Since generalized forces correspond to generalised displacements in a work sense, the generalised forces of assemblages are net force in the direction of the joint displacements. Particularly, the kth generalised force, Rk, is equal to the sum of the external force, Q_k , and the internal forces corresponding to the joint displacement, qk.

Therefore, for an n-degree of freedom system composed of NE elements, the condition of equilibrium gives:

$$Q = \sum_{i=1}^{NE} F_q{}^i \qquad (3.4)$$

where Q = n - dimensional applied joint force vector, that is, generalised external force vector.

Fq^i = n - dimensional internal force vector supplied by element i, that is the generalised force vector of element i.

Since the member code matrix identifies the element displacements, Dj^i, that are equated with the joint displacements, qk, it also serves to identify the corresponding element forces, Fj^i, that balance the applied joint force, qk.

Accordingly, the generalised force vector of element i, Fq^i, can be obtained from the global force vector of element , F^i, as follows.

FORCE TRANSFORMATION: $F^i \xrightarrow{M} Fq^i$

1. Match the rows of F^i with the entries of the ith row of M.
2. Transfer every component of F^i that corresponds to a positive integer k to the k- th row of Fq^i.
3. Assign the value zero to every row of Fq^i that does not receive a contribution from F^i.

3.5 Coordinate Transformation

Since element models are expressed in local coordinates and assembled in global coordinates, coordinate transformations are required.

Figure 3.5 depicts the local and global coordinate axes for an element of a plane frame. The local 1 and 2 axes are assumed to remain in the vertical global plane X-Y, so that both local and global 3 axes are coincident, Livesley (1978). From figure 3.5 , the rotation matrix is

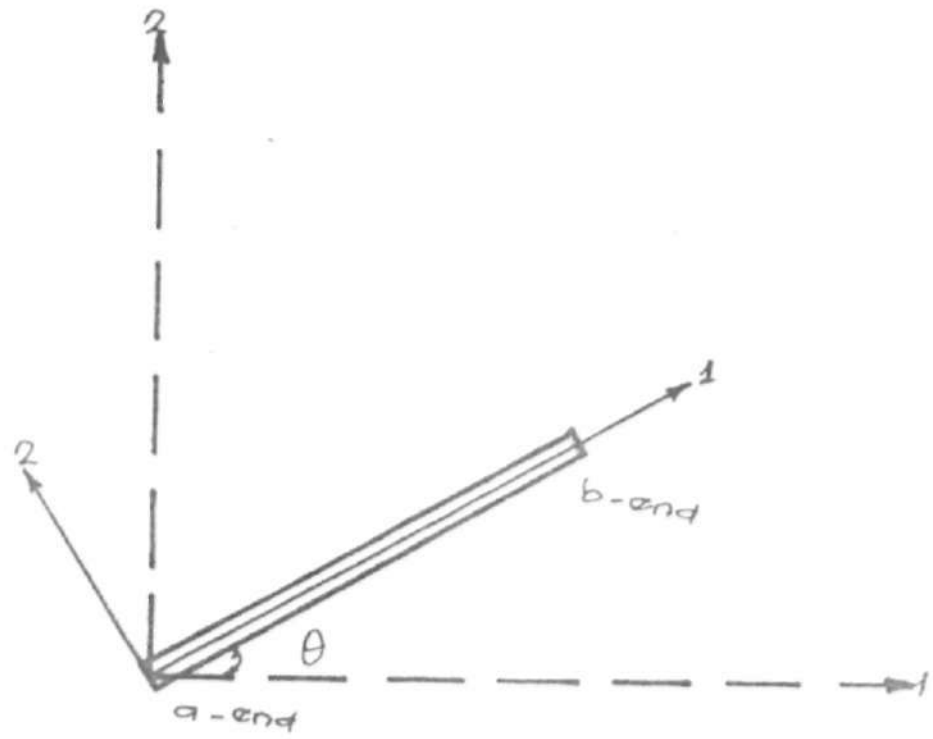


FIG. 3.5. LOCAL AND GLOBAL CO-ORDINATES FOR AN ELEMENT OF PLAE FRAME

$$\lambda = \begin{bmatrix} C1 & C2 & 0 \\ -C2 & C1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad \begin{aligned} C1 &= \cos\ \theta \\ C2 &= \sin\ \theta \end{aligned} \qquad (3.6)$$

The rotation angle θ is measured from global 1 - axis to the local 1 - axis; its positive sence is counterclock wise. The rotation matrix (Eq 3.6) is used in transformation between local and global co-ordinates to formulate displacement analysis technique. Specifically, these transformations are of the form

$$d = \Lambda D \qquad (3.7a)$$

and

$$F = \Lambda^T f \qquad (3.7b)$$

Where d and D are the local and global element displacement vectors, f and F are local and global element force vectors, and Λ is the transformation matrix from global to local coordinates.

$$\Lambda = \begin{bmatrix} \lambda & 0 \\ 0 & \lambda \end{bmatrix} \qquad (3.8)$$

λ is defined in Eq. 3.6.

3.6 Assembly Process (Stiffness & force)

In this section, the matrix displacement method is presented in a form which makes it suitable for

computer analysis of frame represented as an assemplage of discrete interconnected elements. Specifically, conditions of compatibility and equilibrium are formulated without reference to a visual image of the structure, and an efficient procedure is employed for the assembly of element models into the system model.

If the local and global reference frames are distinct, the local element model.

$$f^i = k^i d^i; \quad i = 1,2.....,NE \tag{3.9}$$

must be transformed into the global element model.

$$F^i = K^i D^i \tag{3.10}$$

Where the global element stiffness matrix

$$K^i = \Lambda^{iT} k^i \Lambda^i \tag{3.11}$$

Eqs. 3.10 and 3.11 are obtained from Eq. 3.9. and the contragradient transformation Eq. 3.7, as follows:

$$F^i = \Lambda^{iT} f^i = \Lambda^{iT} k^i d^i = \Lambda^{iT} k^i \Lambda^i D^i$$

$$= K^i D^i \tag{3.12}$$

The global element model is next transformed into the generalised element model

$$Fq^i = Kq^i q \tag{3.13}$$

by conditions of compatibility. Finally, the substitation of eq. 3.13 into the equation of equilibrium, eq. 3.4, yields the system model

$$K_q = Q \qquad (3.14)$$

Where the system stiffness matrix

$$K = \sum_{i=1}^{NE} Kq^i \qquad (3.15)$$

The generalised element stiffness matrix, Kq^i, can be constructed efficiently from the global element stiffness matrix, K^i, with the aid of the member code matrix as follows Holzer (1985)

STIFFNESS MATRIX TRANSFORMATION:

$$K^i \xrightarrow{\quad M \quad} Kq^i$$

1. Match the rows and columns of K^i with the entries of the ith row of M.
2. Transfer every coefficient of K^i whose row and column correspond to positive integers j and k to the j-th row and k-th column of Kq^i.
3. Assign the value zero to every location of Kq^i that does not receive a contribution from K^i.

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Eq. 3.14 represents a set of simultaneous, non-homogen... algebraic equations in the unknown joint displacements. The solution to eq. 3.14 is unique if the system stiffness matrix is nonsingular, that is, if K has rank n. Physically,

this means that the assemblage is sufficiently constrained to prevent (finite or infinitesimal) rigid-body displacement. Accordingly, the initial configuration is a configuration of stable equilibrium.

3.7 Formulation of Global Element

To apply the matrix displacement method to interconnected framethe global element stiffness matrix need to be formulated. The local element model (eq. 2.51).

$$f = kd \tag{3.16a}$$

where

$$k = \begin{bmatrix} k_{aa} & k_{ab} \\ k_{ba} & k_{bb} \end{bmatrix}$$

$$= \alpha \left[\begin{array}{ccc|ccc} \beta & 0 & 0 & -\beta & 0 & 0 \\ 0 & 12 & 6L & 0 & -12 & 6L \\ 0 & 6L & 4L^2 & 0 & -6L & 2L^2 \\ \hline -\beta & 0 & 0 & \beta & 0 & 0 \\ 0 & -12 & -6L & 0 & 12 & -6L \\ 0 & 6L & 2L^2 & 0 & -6L & 4L^2 \end{array}\right] \tag{3.16b}$$

and

$$\alpha = EI/L^3, \qquad \beta = AL^2/I, \quad \gamma = \alpha\beta = AE/L$$

The substitution of the partitioned Λ - Matrix (eq. 3.8) and the partitioned k - Matrix (eq. 3.16b) yield the global element stiffness matrix in the form.

$$K = \begin{bmatrix} Kaa & Kab \\ Kba & Kbb \end{bmatrix} \qquad (3.17)$$

where

$$\begin{aligned} Kaa &= \lambda^T \; k_{aa} \; \lambda \\ Kab &= \lambda^T \; k_{ab} \; \lambda \\ Kba &= \lambda^T \; k_{ba} \; \lambda \\ Kbb &= \lambda^T \; k_{bb} \; \lambda \end{aligned} \qquad (3.18)$$

Since K is symmetric, it is sufficient to compute the coefficient of Kab and the upper triangle portions of Kaa and Kbb. For example, by Eqs. 3.6, 3.16, and 3.18

$$Kaa = \alpha \begin{bmatrix} C1 & -C2 & 0 \\ C2 & C1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} B & 0 & 0 \\ 0 & 12 & 6L \\ 0 & 6L & 4L^2 \end{bmatrix} \begin{bmatrix} C1 & C2 & 0 \\ -C2 & C1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} g1 & g2 & g4 \\ & g3 & g5 \\ & & g6 \end{bmatrix} \qquad (3.19)$$

The resulting global stiffness matrix of the frame element can be expressed as:

$$*K = \begin{bmatrix} g1 & g2 & g4 & -g1 & -g2 & g4 \\ & g3 & g5 & -g2 & -g3 & g5 \\ & & g6 & -g4 & -g5 & g7 \\ & & & g1 & g2 & -g4 \\ & & & & g3 & -g5 \\ & & \text{Sym.} & & & g6 \end{bmatrix} \qquad (3.20)$$

where

$$g1 = \alpha (\beta C_1^2 + 12C_2)$$
$$g2 = \alpha C_1 C_2 \quad (\beta - 12)$$
$$g3 = \alpha (\beta C_2^2 + 12C_1^2)$$
$$g4 = -\alpha\, 6LC_2 \qquad (3.21)$$
$$g5 = \alpha\, 6LC_1$$
$$g6 = \alpha\, 4L^2$$
$$g7 = \alpha\, 2L^2$$
$$\alpha = EI/L^3$$
$$\beta = AL^2/I$$

3.8 Element Actions

In presence of element loads, the joint displacement no longer represents generalised displacements of assemblage, Holzer (1985); that is, the joint displacements are not sufficient to define the configuration of elements subjected to loads.

However, the joint displacements, the element -end forces, and the joint forces can be computed by a procedure known as resolution of actions. It includes load resolution, analysis of an equivalent joint load system and response superposition.

3.8.1 Resolution of Actions

Element actions may consist of loads, temperature changes, element imperfections, prescribed displacements (such as support settlements) etc. The actions of the structure are transformed into equivalent joint loads by the resolution.

$$\bar{I} = \hat{I} + I \qquad (3.22)$$

where

$\bar{I}$ = actual actions of the structure; they may consist of element and joint actions

$\hat{I}$ = Fixed joint actions; they are composed of the actual element actions and joint loads required to prevent joint displacement.

$\mathbf{l}$ = equivalent joint loads.

Since the joints corresponding to $\hat{\mathbf{l}}$ do not experience displacements, the element - end forces are fixed-end forces that can be computed from formula developed for specific element loads.

Note that $\mathbf{l}$ contains only joint loads because the element actions are introduced in $\hat{\mathbf{l}}$ and it follows from eq. 3.22 that

$$\mathbf{l} = \bar{\mathbf{l}} - \hat{\mathbf{l}} \tag{3.23}$$

Thus the equivalent joint loads can be obtained by substracting the fixed joint loads from the actual loads. Hence, the response to $\mathbf{l}$ can be determined by the matrix displacement method.

In matrix form, the equivalent joint load can be expressed as

$$Q = \bar{Q} - \hat{Q}$$

where

$\bar{Q}$ = actual joint load vector

$\hat{Q}$ = fixed joint load vector

Q = equivalent joints load vector.

$\bar{Q}$ is prescribed and $\hat{Q}$ can be computed as follows:

1. For each element subjected to actions, the local fixed end $\hat{f}^i$, is computed and transformed into the global fixed end force vector, $\hat{F}^i$

2. The generalised fixed end force vector, Fq^i, is determined by the force transformation(section 3.4.2)

$$F^j \xrightarrow{\quad M \quad} F_q{}^i \tag{3.25}$$

3. The condition of equilibrium eq 3.4 , is imposed to yield

$$Q = \sum_{i=1}^{NE} Fq^i \tag{3.26}$$

Once the responces to $\hat{1}$ and 1 are determined, they are superimposed , eq. 3.22, to yield the actual response. In particular the actual element force vectors can be expressed as

$$\bar{f}^i = f^i + \hat{f}^i \tag{3.27}$$

where

$$f^i = k^i d^i$$

Then the actual force joint force vector Pj can be computed.

Note that the joint displacement corresponding to $\bar{1}$ and 1 are identical because, the joint displacements corresponding to $\hat{1}$ are zero by definition

i.e.

$$\bar{q} = q + \hat{q} = q \tag{3.28}$$

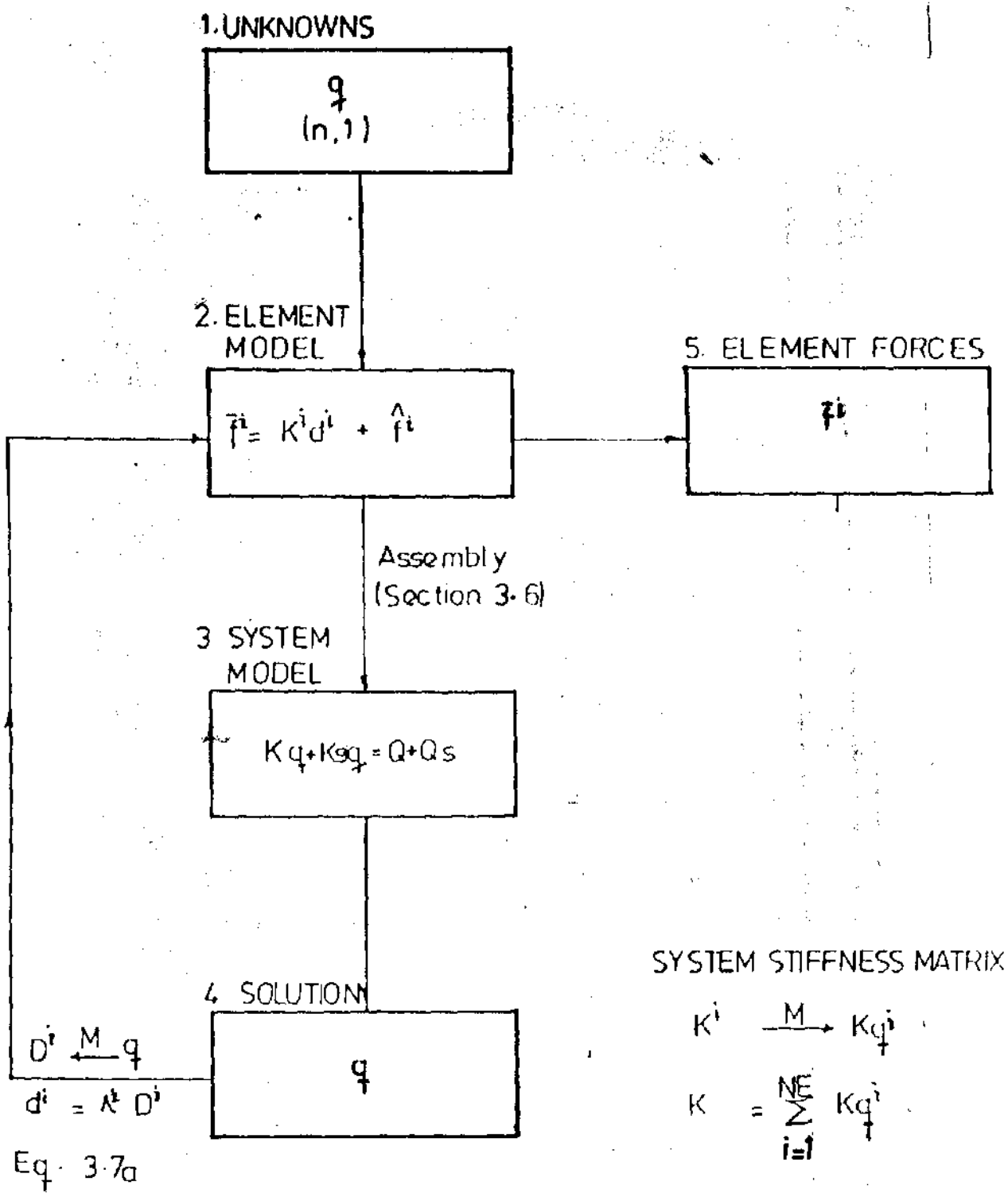
because

$$\hat{q} = 0$$

3.9 Summary

The complete process of matrix displacement method with element actions is presented in a form, fig.3.6, that facilitates computerization. The key steps are

1. The unknown joint displacement are selected as the independent variables.
2. The element models are formulated eq. 3.27
3. The element models are assembled into the system model, the model of the structure, by imposing the conditions of compatibility and equilibrium. The conditions of equilibrium balance the applied joint forces and the element forces in the directions of the unknown joint displacements. This assures equilibrium of the assemblages. The system model represents a set of simultaneous algebraic equations in the unknown joint displacements.
4. The system model is solved for the joint displacements.
5. The element end forces are computed by substituting the values of joint displacements into the element model equations.
6. The applied and reactive external forces at a joint are then computed from element forces.



Eq. 3.7a

n = number of system dof

m = number of element dof

NE = number of elements

Fig. 3.6 : Matrix Displacement method with Element Actions And Spring Model (Holzer) (1985)

CHAPTER FOUR

SIMULATION MODEL

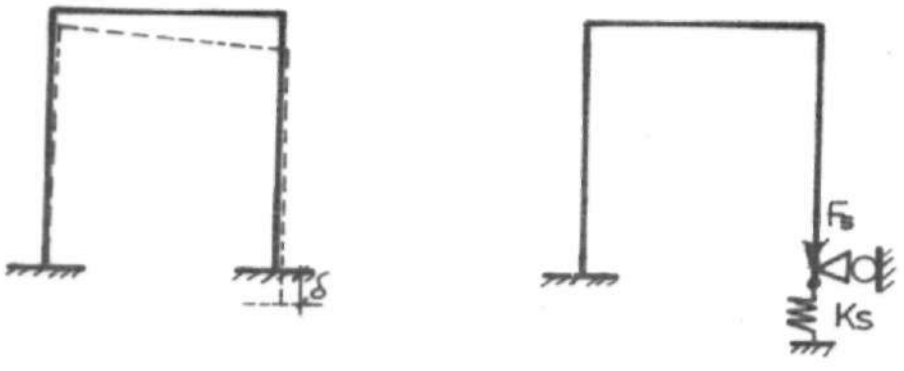
It is necessary to simulate the structure with a simple model to understand the behaviour of whole structure. Three different simulation models and a parametric study are considered as follows:

1. A Direct spring model
2. Settlement of beam and frame
3. Stiffness variation of beam and frame.
4. Parametric study (e.g. Geometry, settlement & stiffness)

4.1 Direct Spring model (William 1978)

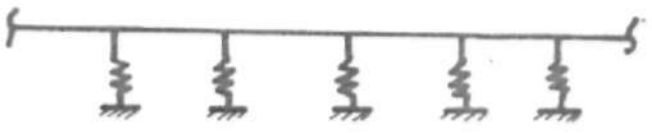
A problem of concern to many engineers is analysis of a structural system resting on an elastic foundation. Examples of such systems are first, a frame structure with support settlement (fig. 4.1a), and second, a continuous building foundation, railtracks, highways or airport-pavements, which can be idealised as beam on elastic foundation (fig. 4.1b).

The basic assumption is that the intensity of the subgrade reaction is proportional to the deflection of support or beam at any point. This assumption greatly simplifies the analysis, as now the frame support or the beam supports are springs with known spring stiffnesses. The matrix analysis of such supports on elastic foundation is easily accomplished with the techniques of frame analysis.



a.

FRAME SUPPORT SETTLEMENT



b.

FIG. 4.1 BEAM ON ELASTIC FOUND.

4.2 Settlement of Beam and Frame (Schodek - 1980)

a. Support settlement in a simply supported structure often causes no bending moment to develop in the structure since it simply relates freely as it settles.

(see fig. 4.2a)

b. Support settlement in a fixed ended structures cause undesirable bending moments to be developed.

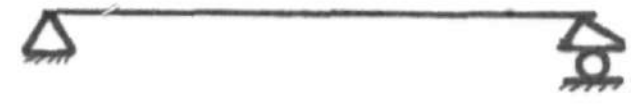
(see fig. 4.2b)

c. Support settlement in continuous beam can cause increased BM to be developed at different locations in the structures over those normally associated with loading. Downward settlement of middle support causes point of inflection to move inward. Thus, increasing the mid-span bending moments. The reaction at the beam ends also increase. (see fig. 4.2c).

d. Support settlement in frame structure can cause increased bending moment to be developed at different location over those normally associated with loading joint(s), here, becomes most critical. (see fig.4.2d)

4.3 Stiffness Variations of Beam and Frame

The different cases of stiffness variations of beam and frame are discussed as below:



a



a

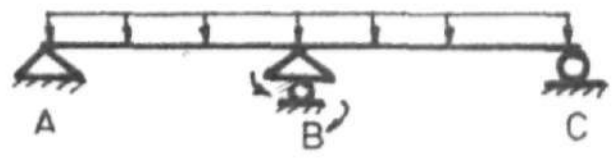


b



b

FIG. 4.2 SETTLEMENT OF BEAM





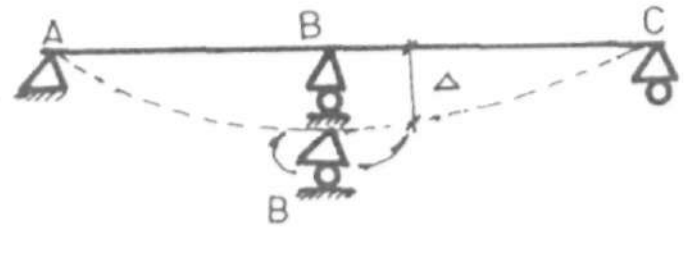




FIG. 4.2C : SETTLEMENT OF CONTINOUS BEAM

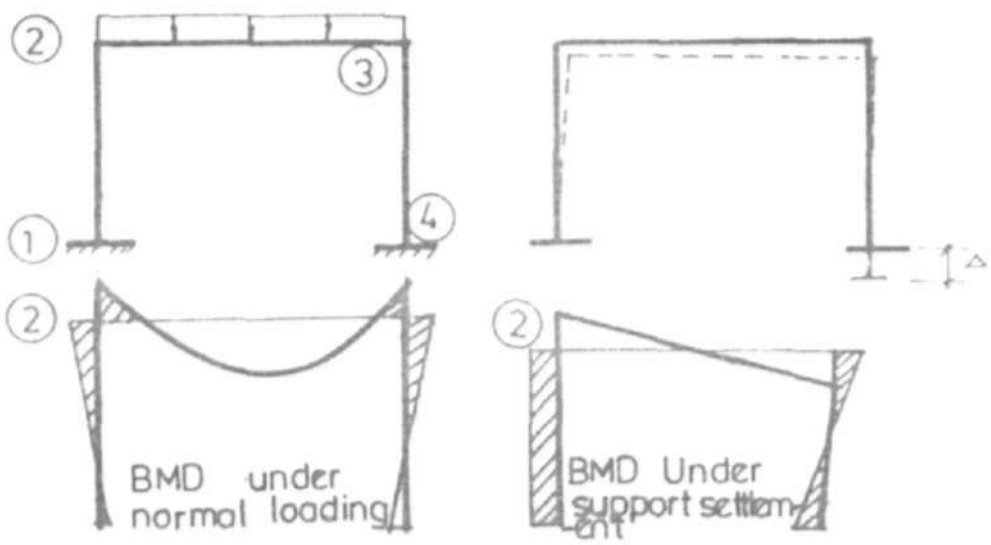


FIG.4.2d: Settlement of frame

CASE - I Stiffness Variation of Beam at the Ends

a. Fixed end beam in which stiffness approaches zero at each end of the beam. (see fig. 4.3a).

b. The reduced stiffness reduces the capacity of the beam to result rotation at that points.Consequently this causes the point of inflextion to be developed at these locations. (see fig. 4.3b)

c. The changed location of inflection points causes a change in bending moment diagram. In this case, the BMD is quite similar to that of simply supported beam. (see fig. 4.3 c)

CASE-II Stiffness Variation of Beam at the Midspan

d. Fixed end beam in which stiffness approaches zero at the centre of the beam reduced stiffness. (See fig. 4.3 d)

e. The reduced stiffness at the centre causes the point of inflection to develop at this point. (see fig.4.3e)

f. The member behaving like two cantilever beams each of length 1/2. The BMD is as shown in fig.4.3d

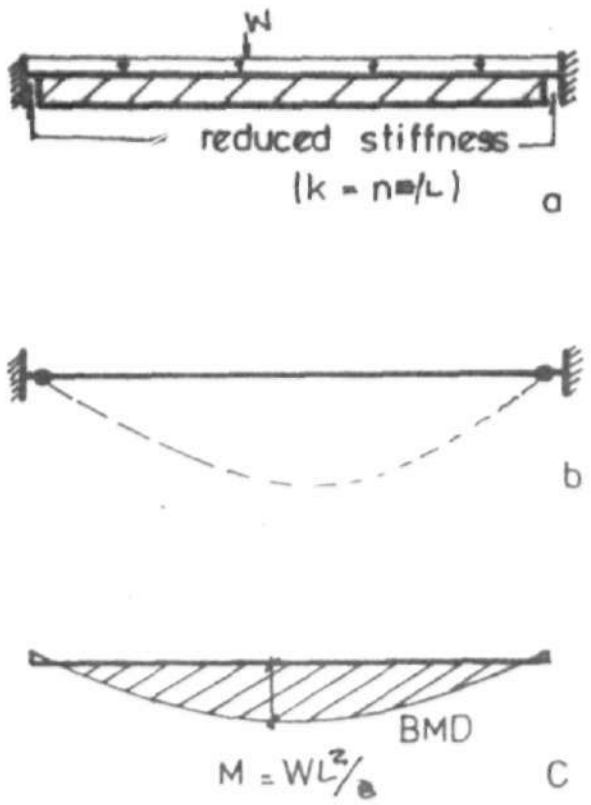


FIG. 4.3 : Stiffness Variation of Beam

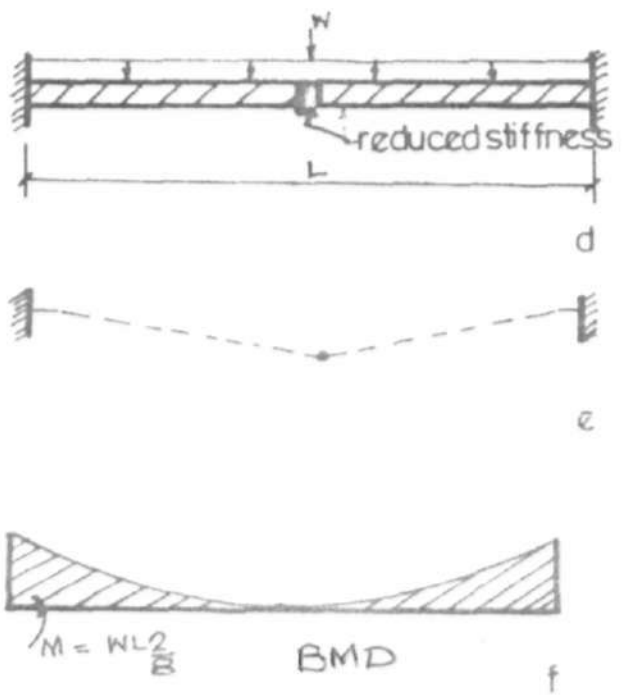


FIG. 4.3 : Stiffness Variation of Beam

CASE III Increased Stiffness at the End of a Beam

g. A fixed end beam with increased depth (stiffness) at each end. (see fig. 4.3g).

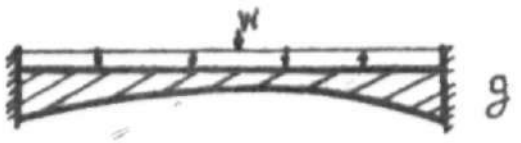
h. Since the beam is stiffer at either end than in the middle, the point of inflection tend to move toward the middle of the beam than they do in beams having a constant cross-section. (see fig. 4.3h).

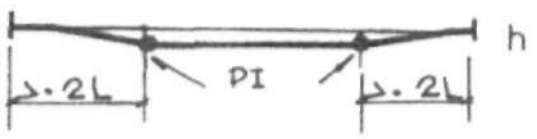
i. The change (movement) of the points of inflections inwards affects the moment diagram. Compared to a beam with constant cross section, more moment is developed at the fixed ends and less at the mid-span. More moment has been attracted to the ends due to increasing member stiffnesses. Note that the sum of positive and negative BM remains $WL^2/8$. The total moment present has thus not been changedonly its distribution. (see fig. 4.3i).

Thus, moment has been attracted by stiff portions of the member. This is a point of fundamental interest from a design view point.

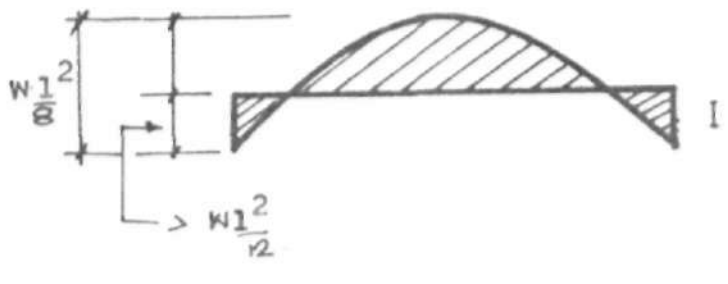
CASE IV Increased Stiffness of a frame

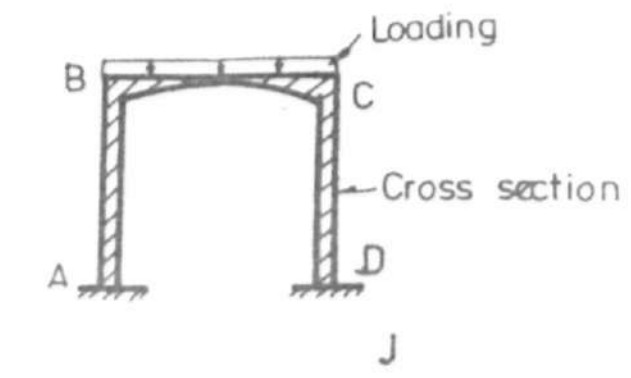
j. In simple frame, the Beam BC can be idealised as the case (III) (See fig. 4.3j). But if you increase the overall stiffness of the structure by same amount, there will not be any difference in force distribution.





PI = Points of inflection





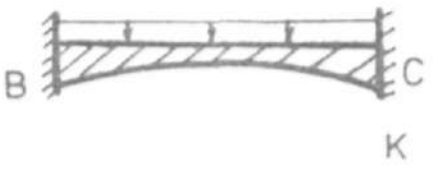


FIG. 4.3: Stiffness Variation of Frame

4.4 Parametric Study

Frame structures are important structures in normal routine design. The behaviour of frame structures for the support settlement conditions and stiffness variations should be sufficiently investigated. For this reason, we select different geometry, settlement and stiffness then analyse the same configuration and compare with the other results. This helps us to see how a particular joint will displace, the magnitude of the forces induced in a member and which member will be critical.

To know the different parameters, a complete table is given for identification. The following parameters are considered.

1. Two storey flats have been selected and the critical different sections A/D (3-bay frame) and B/C (2-bay frame) are analysed under normal loading, and load cases and load combinations. The preliminary design cross-sectional dimensions are considered here.

2. The geometry of the two storey flats is changed at sections A/D and B/C i.e. 1 storey and simple frame.

3. Different conditions for support settlements like external, internal and differential settlements are considered for all the different geometries mentioned in (2) above.

4. . 1 bay simple frame and 1 bay-one storey frame is also considered and analysed under normal loading conditions and support settlements.

5. Finally, the analysis of frame at sections A/D and B/C under various dimensional changes (stiffness) like 10% & 25% increase in cross sectional area is considered.

CASE	STRUCTURAL GEOMETRY	STRUCTURAL CODE NUMBER(SCN)	SUPPORT SETTLEMENT(Δ)
A.	3 bays and 2 storeys (See fig. 4.4A)	G05	Undernormal loading
		G31	20mm Δ at (13)
		G32	20mm Δ at (9)
		G33	1 mm Δ at (9)
			2 mm Δ at (13)
B.	2 bays and 2 storeys (see fig.4.4B)	G06	undernormal loading
		G35	20mm Δ at (1)
		G36	20mm Δ at (8)
		G37	5mm Δ at (2)
			10mm Δ at (1)
C.	3 bays and 1 storey (see fig.4.4 C)	G41	20mm Δ at (10)
		G42	20mm Δ at (7)
		G43	10mm & 20mm Δ at (7) & (10) respectively.

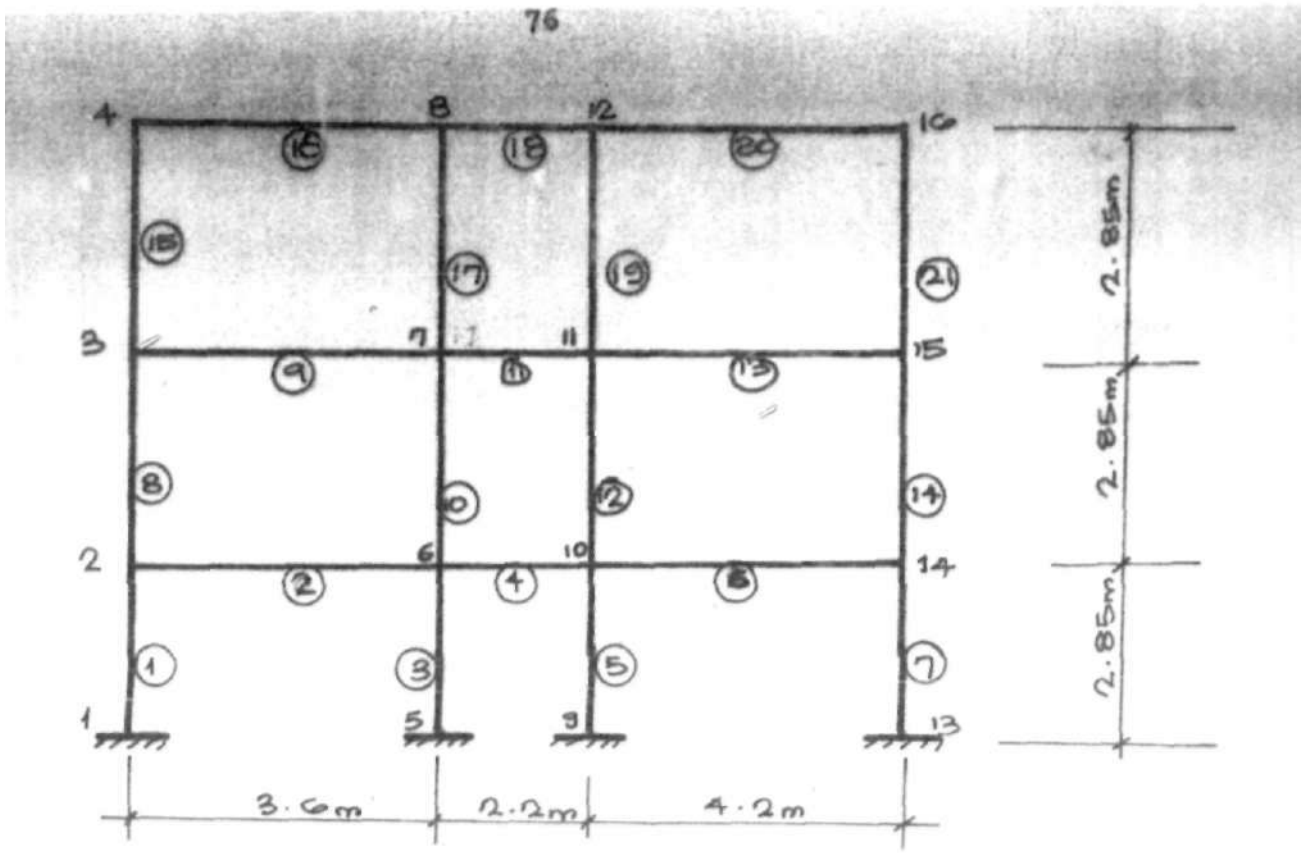


FIG. 4.4A 3 BAYS & 2 STOREYS FRAME

AT SECTION A/D

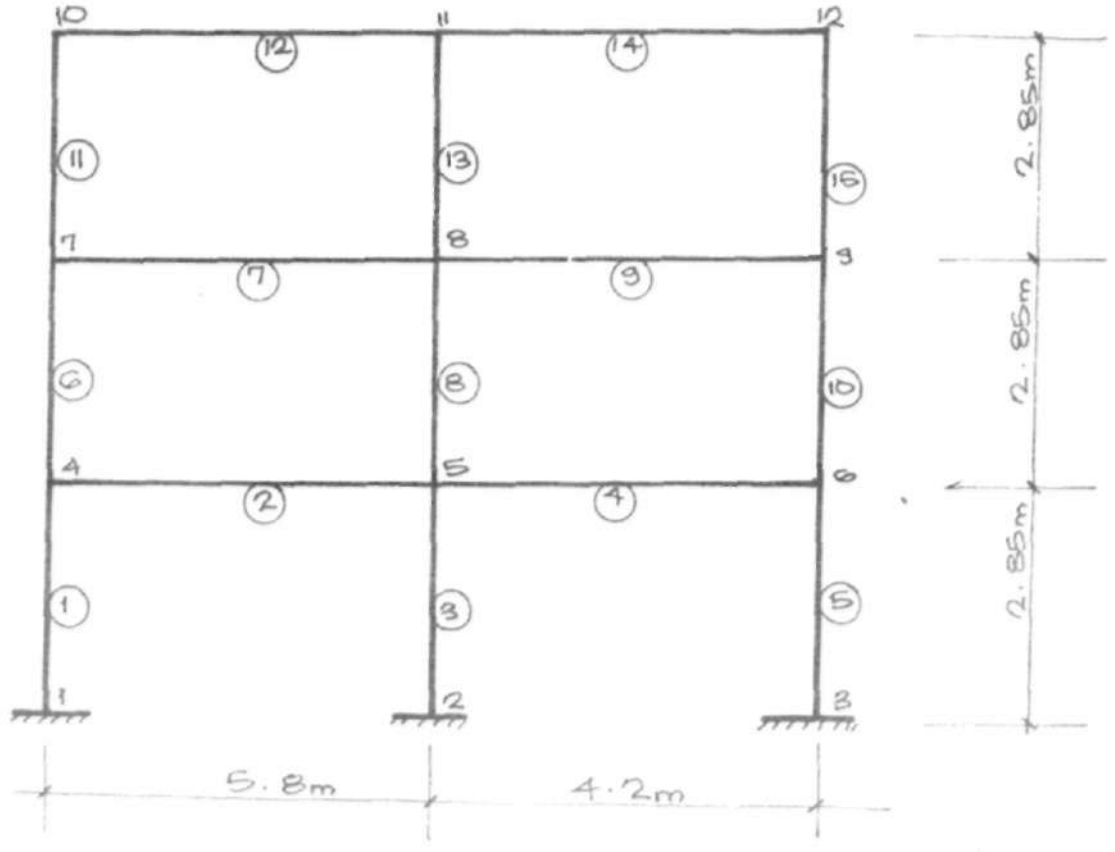


FIG. 4.4B 2 BAYS & 2 STOREYS FRAME

AT SECTION B/C

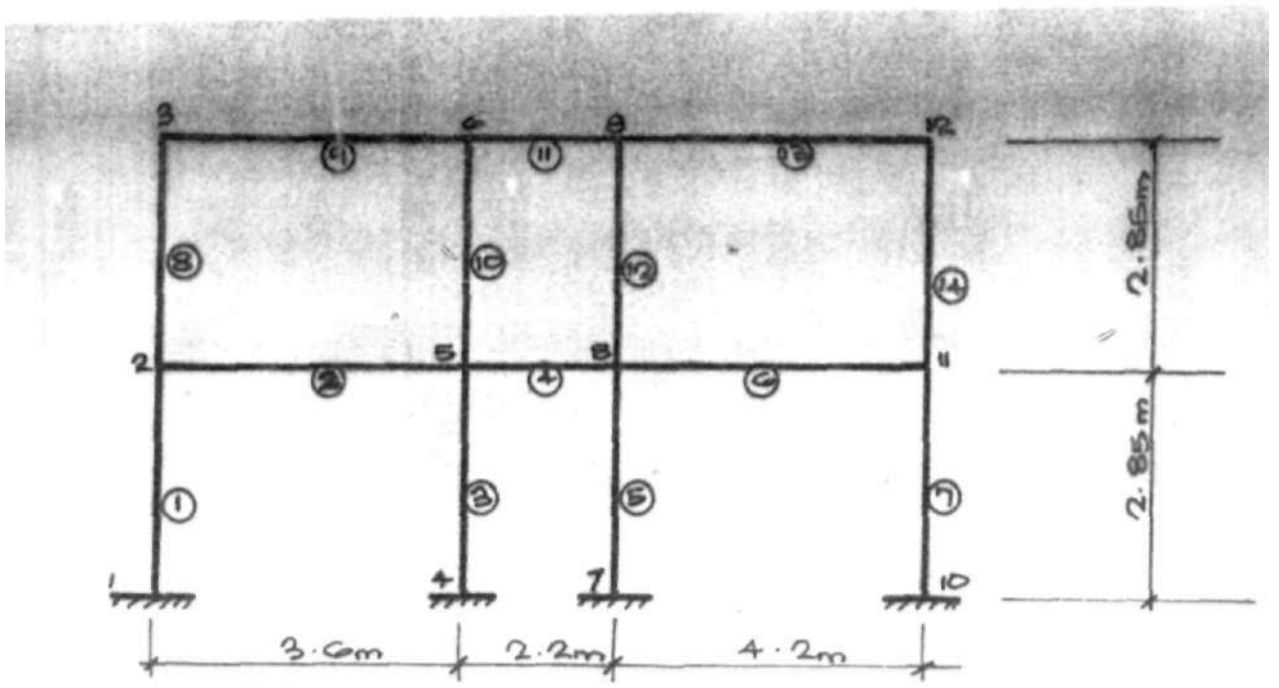


FIG. 4.4C 3 BAYS & ONE STOREY FRAME

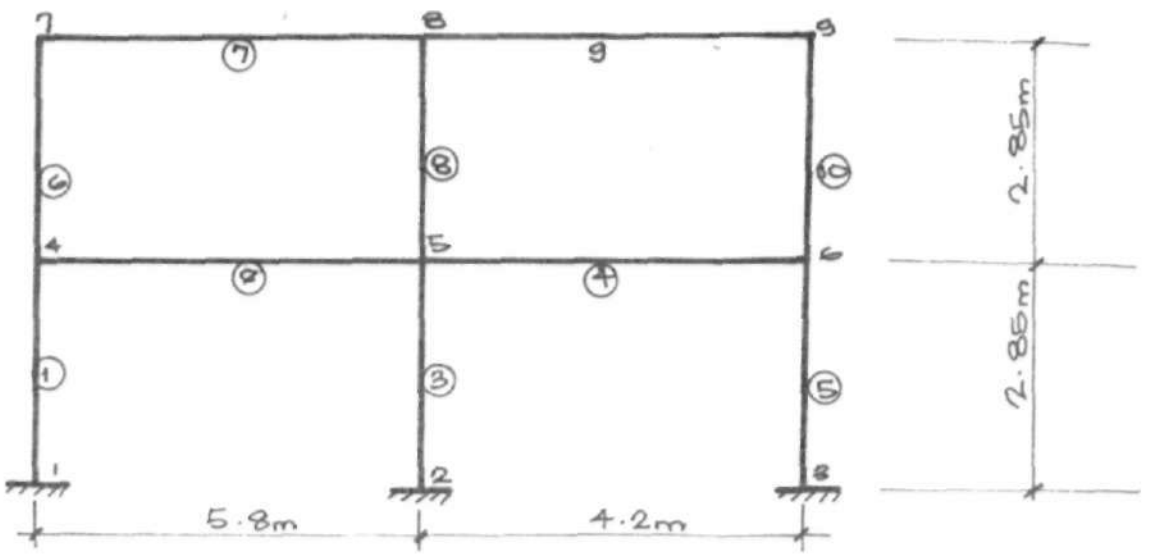


FIG. 4.4D 2 BAYS & ONE STOREY FRAME

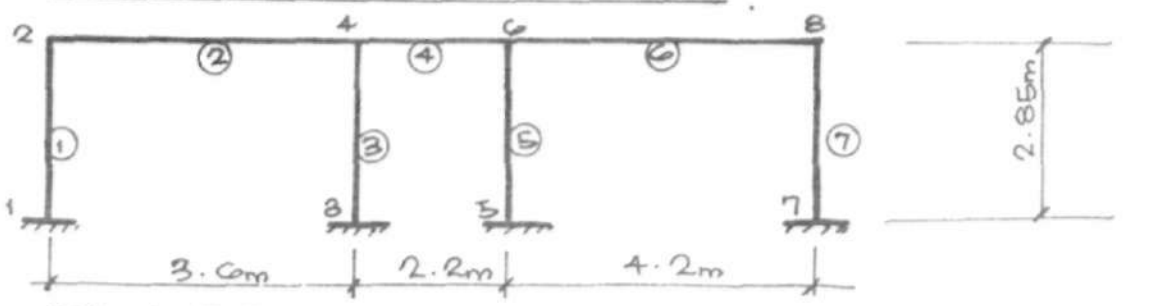


FIG. 4.4E 3 BAYS SIMPLE FRAME

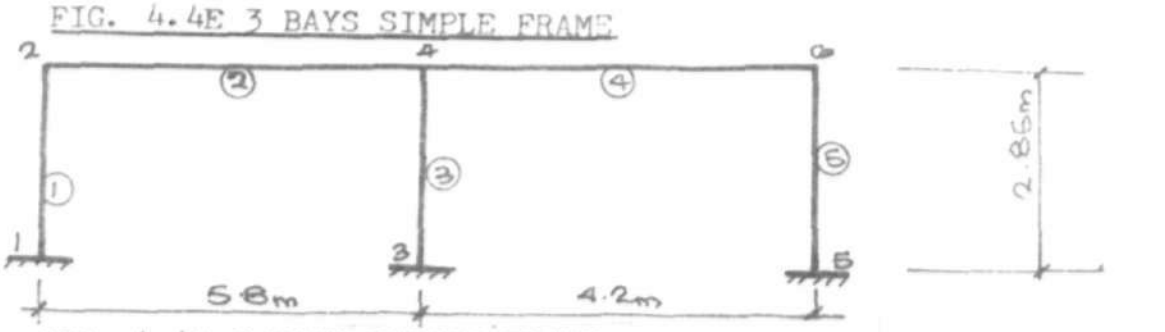


FIG. 4.4F 2 BAYS SIMPLE FRAME

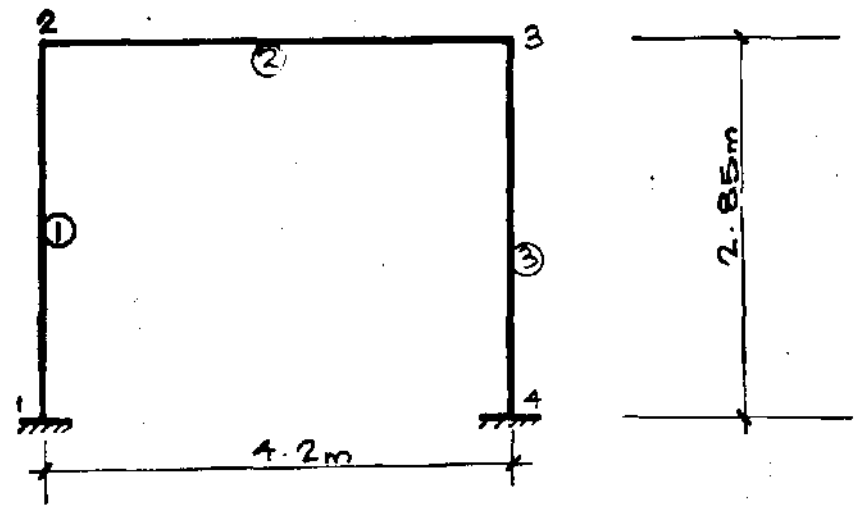


FIG. 4.4G ONE BAY SIMPLE FRAME

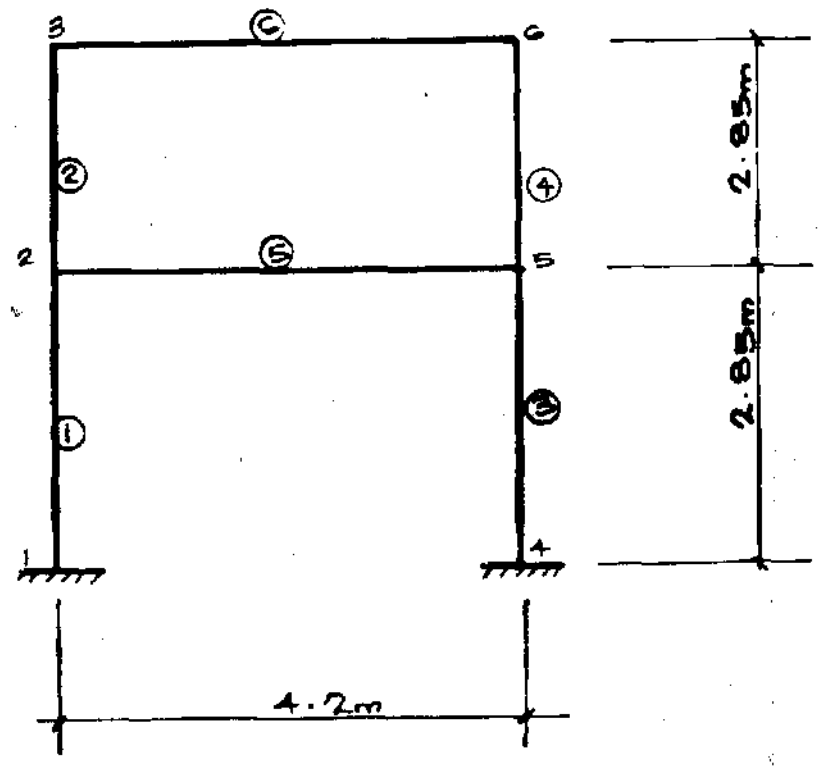


FIG. 4.4H ONE BAY ONE STOREY FRAME

D.	2 bays and 1-storey (see fig.4.4 D)	G45	20mm Δ at (1)
		G46	20mm Δ at (2)
		G47	20mm and 10mm Δ at (2) & (1)Resp.
E.	3bays simple frame (see fig.4.4 E)	G51	20mm Δ at (7)
		G52	20mm Δ at (5)
		G53	10mm & 20mm Δ at (5) & (7) respectively
F.	2 bays simple frame (see fig.4.4 F)	G55	20mm Δ at (1)
		G56	20mm Δ at (3)
		G57	5mm and 10mm Δ at (3) &(1)respectively.
G.	1 bay simple frame (see fig.4.4 G)	G61	under normal loading
		G62	10mm $\Delta^{(DL+LL)}$ at (4)
H.	1 bay and one storey (see fig. 4.4 H)	G65	under normal loadings
		G66	10mm $\Delta^{(DL+LL)}$ (a) (4)
I.	3 bays and 2 storeys (see fig.4.4 I)	G07	10% increase in dimension(stiffness).
		G09	25% increase in stiffness.
J.	2 bays and 2 storeys (see fig. 4.4 J)	G08	10% increase in stiffness.
		G10	25% increase in stiffness.

CHAPTER FIVE

COMPUTER IMPLEMENTATION OF THE MATRIX DISPLACEMENT METHOD

5.1 INTRODUCTION

General theories and formulations of matrix displacement method for PFS analysis under support settlement are presented in this study. The objective in this chapter is to discuss some important computational aspects pertaining to the implementation of the matrix displacement method.

It seems possible, by using many elements, to approximate any PFS with complex boundary and loading conditions to such a degree that an accurate analysis can be carried out. In practice, however, obvious engineering limitations arise, a most important one being the cost of analysis. As the number of elements is increased, the manpower required to prepare the relevant data and interpret the result will increase, and also a larger amount of computer time is needed for the analysis. Furthermore, the limitations of the program and the computer may prevent the use of a larger number of elements to idealise the structure. The limitations may be due to high speed and back up (low-speed) storage available, or the round-off and truncation errors occuring in the analysis because of finite precision arithmetic. Also the malfunctioning of a hardware component, if the analysis is carried out using many computer hours, is possible. It is therefore desirable to use efficient programming techniques.

The effectiveness of a program depends largely

on efficient programming method and sophisticated use of the available computer hardware and software. Nevertheless, some effective computer programs have been developed on micro computers.

In the following, the design of matrix displacement method of analysis program, in which largely computer - dependent procedures are used, is discussed. An actual frame structure idealised as an assemblage of interconnected elements is assumed. The process of analysis consists of essentially four phases of the computer program:

1. Input pre-processing
2. Assembly & Solution.
3. Calculation of element - end forces and support reactions.
4. Output Results of Analysis.

A computer program using all the important features is presented in Appendix IV. As might be imagined, there is no unique optimum program organisation and various different and effective strategies are currently followed as in Batbe and et al (1974), Bathe (1975), and Harrison (1980), Parts I & II. In addition, new ideas may be developed, particularly as new computer equipment becomes available.

5.2 Computer Program Organisation

The listing of the program PF is presented in Appendix Iv . Although, the Code PF is simplified in various areas, it shows all the important features of more

general codes. The main objective in the presentation of the program is to show the overall flow of a typical matrix displacement method program.

Figure 5.1 shows a flow chart of the program modules. The user's guide is presented in Appendix I. The program can be understood to be consist of essentially four modeles: (see fig. 5.2 a, b, c& d).

1. INPUT PROCESSING - This module accepts all input data, computes system degree of freedom and half-band width, accepts spring data, establishes member-code-matrix, calculates fixed-end forces, resolves applied action and finally stores data into appropriate file for further processes.

2. ASSEMBLY & SOLUTION PROCESS - At this module, first of all data required for assembly process are read from file and the module computes global element stiffness matrix and stores the results into file. Secondly, the module using K and Q, solves the equilibrium equations using triple matrix decomposition technique and stores the resulting displacements, q, into file.

3. COMPUTATION OF ELEMENT END FORCES & SUPPORT REACTIONS - Reads data required for displacement transformations and computation of element end forces. Performs the computations and stores the resulting element-end force into the file. And secondly, it computes the support reactions.

4. OUTPUT PROCESSING - This post-processing module reads displacements, element-end forces, and out put information from the file.

These modules are stored as separate programs (PF 1-4) on the Mini Floppy Disk (see Table 5.1 for details) and the low-speed storage allocations used during the analysis process, i.e. the file.

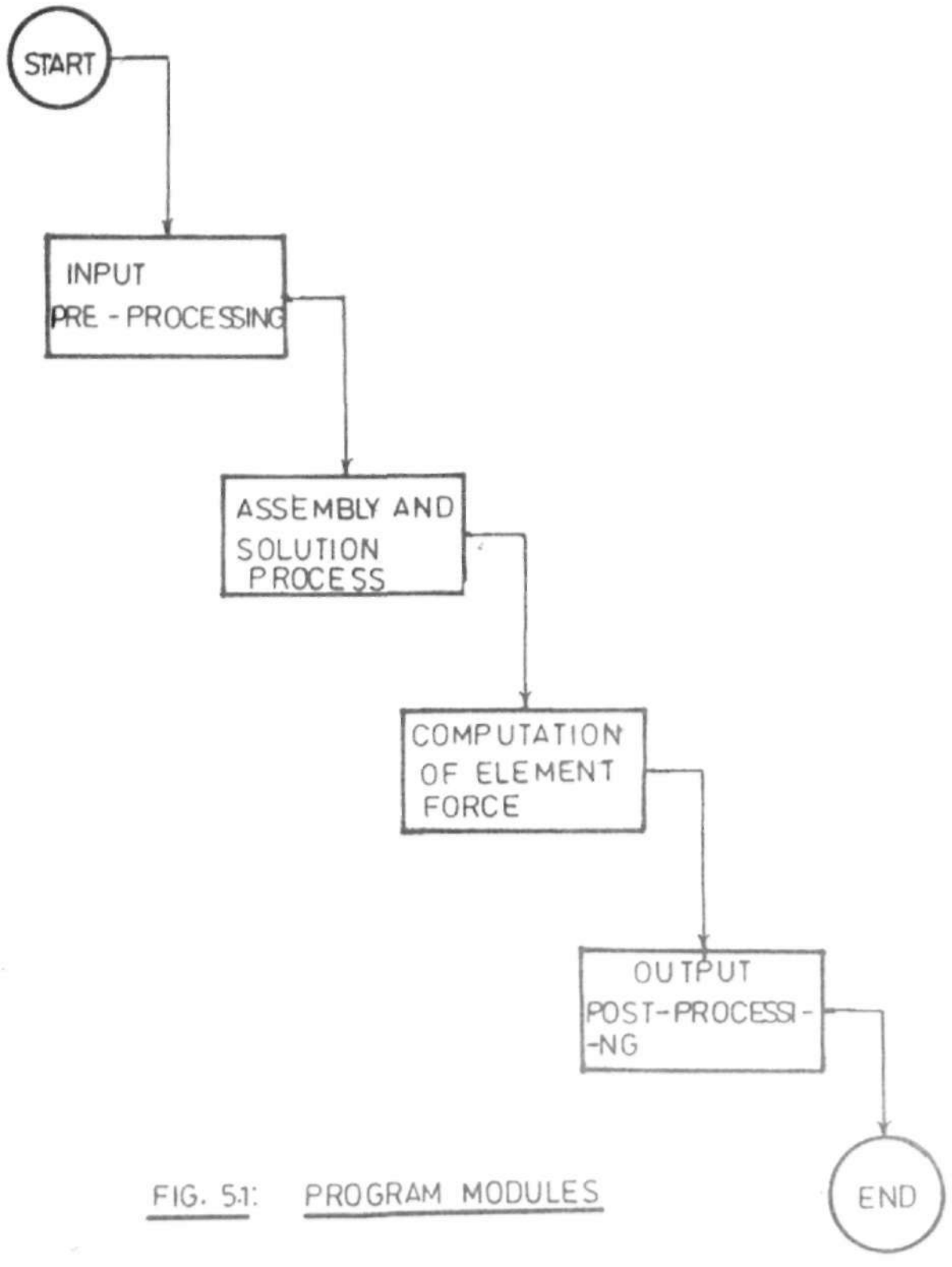


FIG. 5.1: PROGRAM MODULES

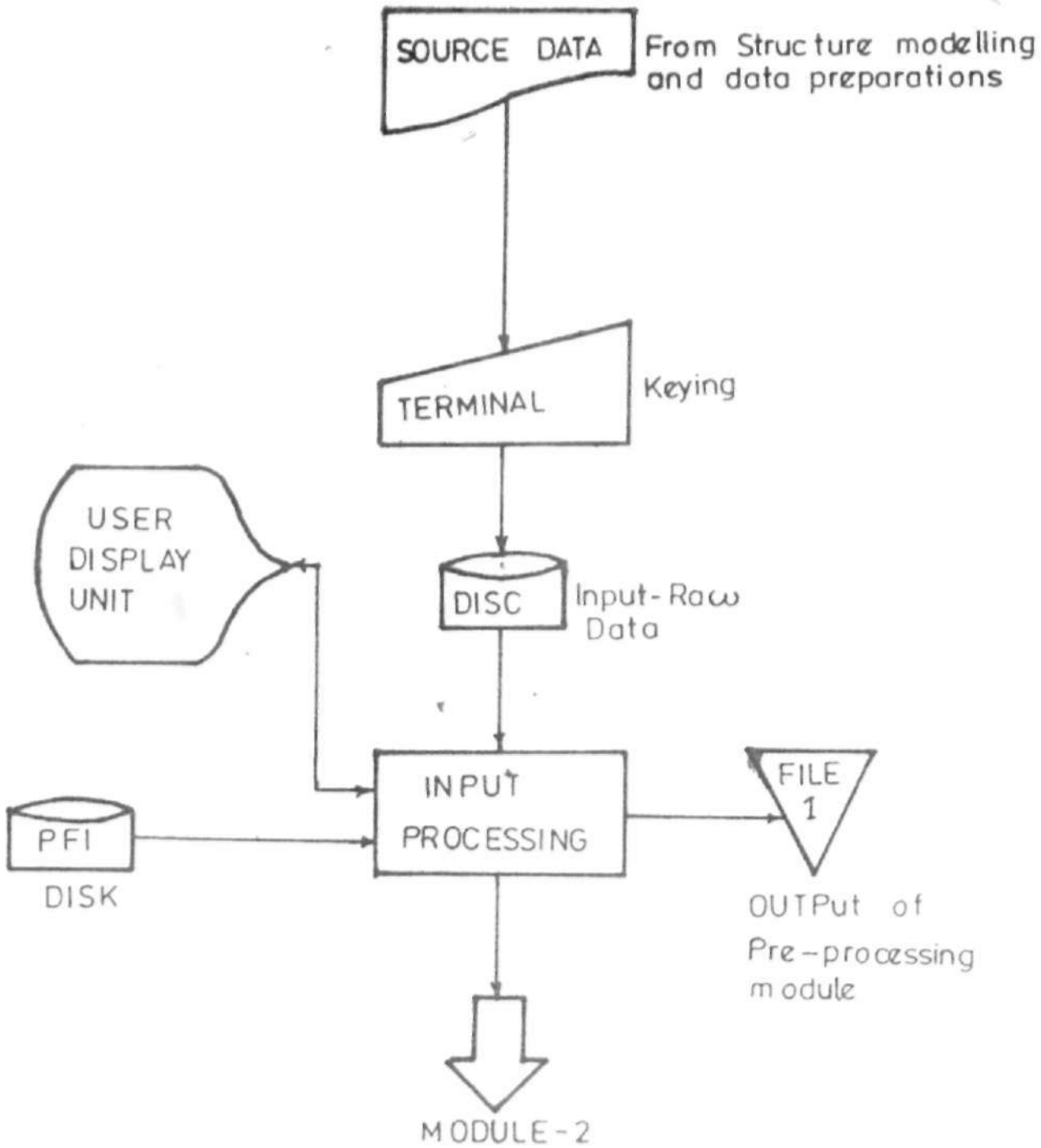


FIG. 5.2a MODULE-1

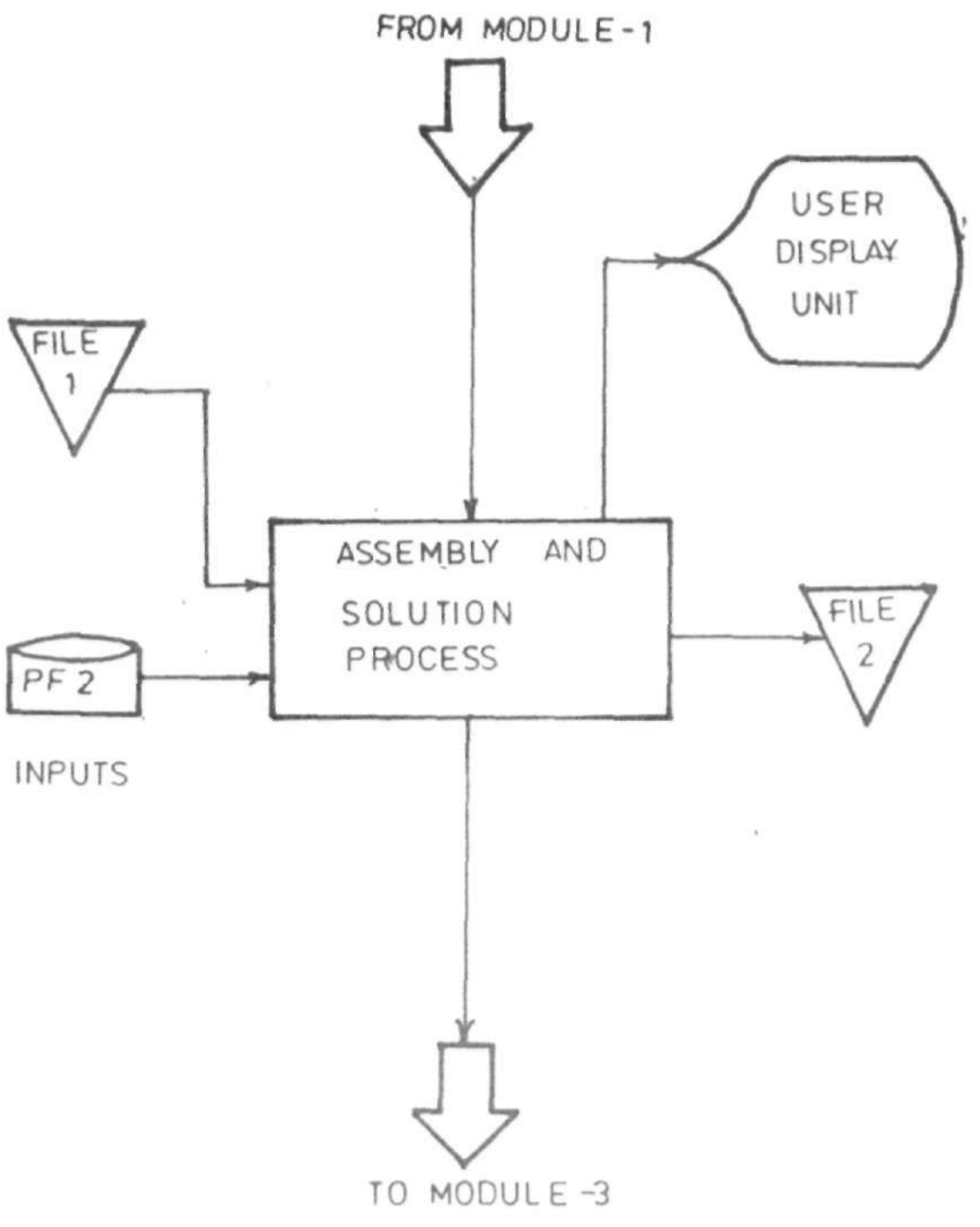


FIG. 5.2b MODULE - 2

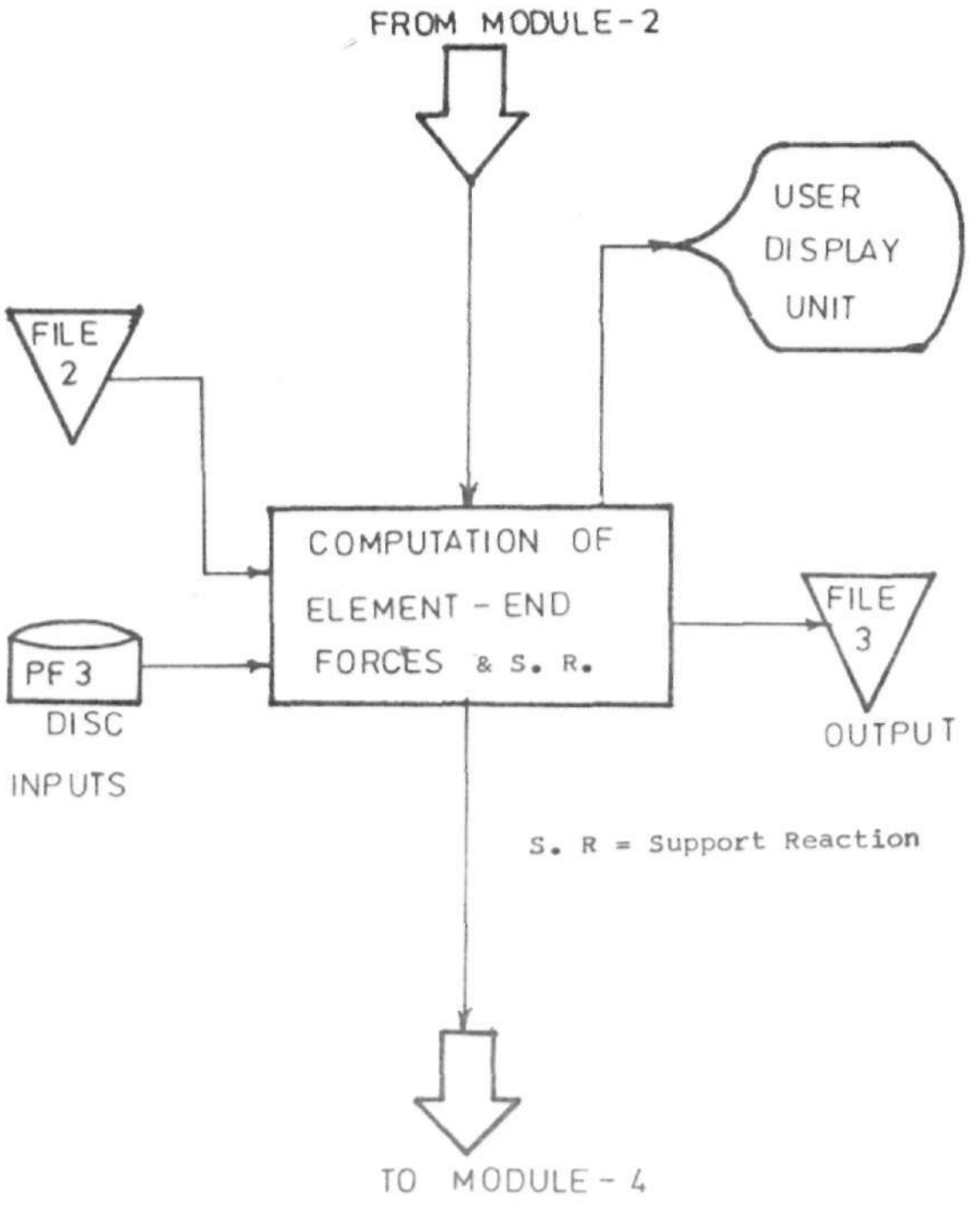


FIG. 5.2C MODULE – 3

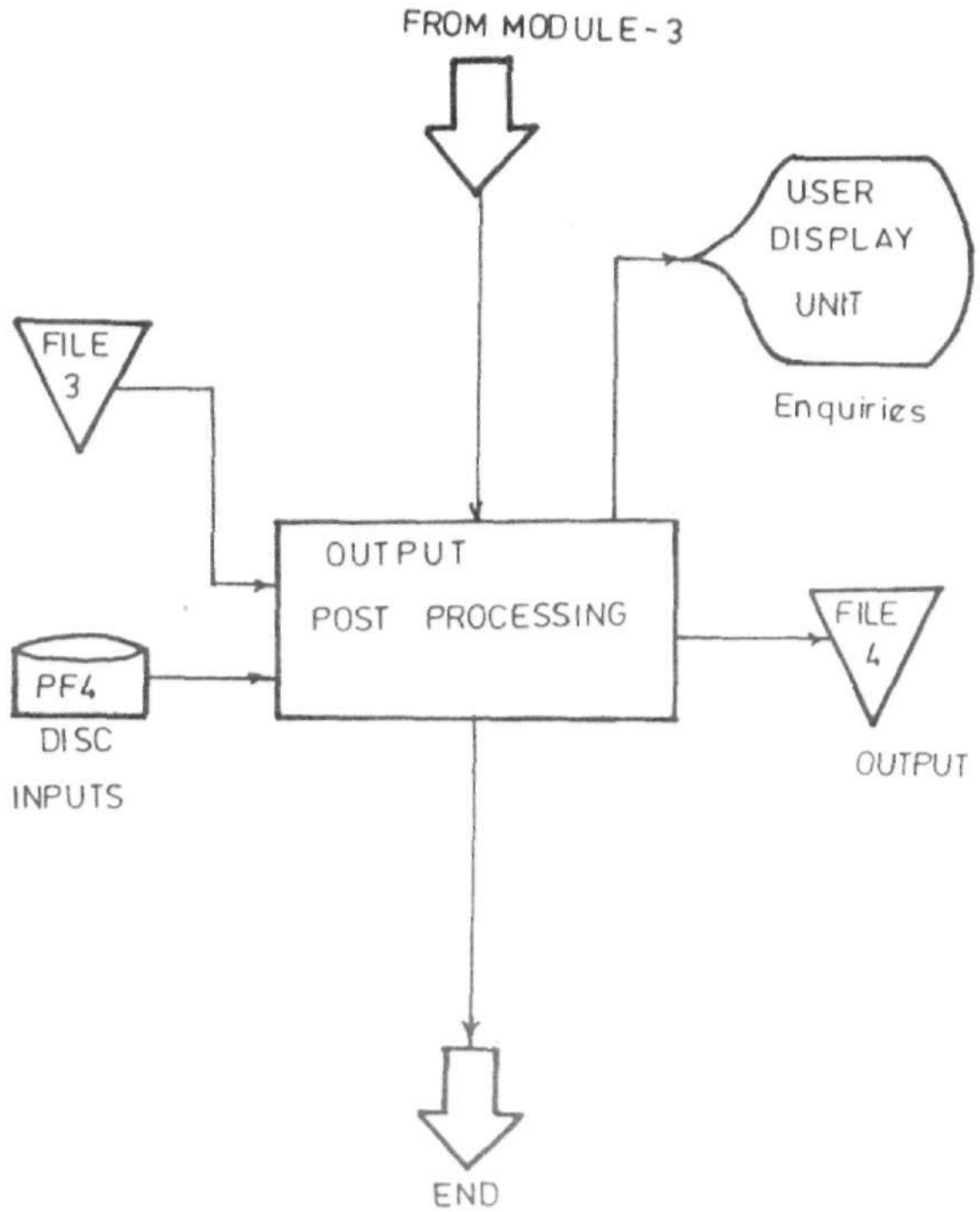


FIG. 5.2 D: MODULE -4

TABLE 5.1. DESCRIPTION OF PROGRAM

MODULE	DESCRIPTION
PF 1	Pre-processing Module: Accepts all input data, generates other information necessary to complete the analysis, and finally stores data into appropriate files for further processes.
PF 2	Assembly and Solution Module: (a) Performs the system stiffness matrix transformation. (b) Solves the equilibrium equations using triple matrix decomposition technique.
PF 3	Computation of Element End Forces & Support Reactions Module: Perform the transformation of assemblage displacements into local axes and computes the element-end forces.
PF 4	Post-processing Module: Performs load combinations and output the desired results.

5.3 PROGRAM INFORMATION FLOW

The first module reads and/or generates all data required for the complete PFS analysis. The input data consists of the following categories:

Problem Title

Control Information

Joint Coordinates

Elements Connectivity

Joints Releases

Spring Stiffnesses

Element's material Properties.

Load Data (Dead, Imposed, Spring Load etc.)

Out-put Information.

The full description of each category is presented in the user's guide (Appendix I). With all the data known, the program continues to generate other information necessary to complete the analysis.

Consider first data that correspond to the joints. The program is set up to allow a maximum of three degree of freedom at each joint-two translations and one rotational. Corresponding to each joint, it must then be identified which of these degrees of freedom shall actually be used in the analysis, that is which of the three possible joint degrees of freedom correspond to degrees of freedom of the assemblage. This is achieved by defining an identification array as follows:

$$JR = NJ * 3$$

where

JR = Joint Releases

NJ = Number of joints.

Element (i,j) in the JR matrix corresponding to the jth degree of freedom at that joint i. If JR (I,J) = 0, the corresponding degree of freedom is defined in the element system; and if JR (I,J) = 1, the degree of freedom is not defined.

Once all active degrees of freedom have been defined by zero (in the JR array) the equation numbers corresponding to these degrees of freedom are assigned. The procedure is to simply scan row after row through the JR array and replace each zero by an equation number which increases successively from 1 to the total number of equations, that is, the total system degree of freedom. At the same time the entries corresponding to the non-active degree of freedom are set to zero.

At this stage, with element connectivity and joint releases data known, the program generates the member - code-matrix, M (see section 3.4.1). This matrix relates to each element degree of freedom and hence the corresponding assemblage degree of freedom. It is convenient to connect array M (I,J), in which entry (i,j) gives the equation number that corresponds to the ith element of which degree of freedom j. The procedure of establishing the connectivity array M (I,J) is achieved by using the element connectivity joint pairs to extract the element's assemblage degrees of freedom from JR array, that is, the connectivity array of each element is determined

from the joints to which the element is connected and the equation numbers that have been assigned to these joints.

Once the array M has been defined, the corresponding element stiffness matrix can be added in compact form to the system stiffness matrix, but the process must take due account of the specific storage scheme used. As explained in Harrison (1980), an effective storage scheme for the system stiffness matrix is to store only the elements on the leading diagonal and up to the half-band witdh.

The triple matrix decomposition technique described in Harrison (1980), is then applied to solve the resulting equilibrium equations. Next, for each element, its assemblage degrees of freedom are transformed to local axes and its end forces for each joint are completed to complete the analysis process.

Once the analysis is completed, PF provides the results in an output-file. Joint displacements (movements and rotation.), and element-end forces (axial forces, shear forces and bending moments) may be displayed numerically on the screen or printer. The numerical results output is formalted to allow a quick comparison of all displacements and forces created by each load combination on an element can quickly be obtained. In addition, out put of results concerning particular elements can be easily obtained.

CHAPTER SIX

DISCUSSION OF RESULTS

The results of analysis of the parametric study have been depicted in the appendix III. In this chapter, special attention is given to mark the effects of parametric study at a particular joint or member. Different tables from the results of analysis are prepared and percentage variations are calculated. The observations and discussions from the comparison are marked:

Finally comments are made on:

- stress level
- satisfaction of CODE requirements
- computing time
- computing scheme.

6.1 Loading Calculations

6.1.1 Loads for Section A/D (see fig. 2.1 a & b)

I. Roof Loading

Dead Load

Z- Purlin & Roofing Sheets (say) = 0.3 kN/m^2

$$\times \frac{3.6}{2} = 0.54 \text{ kN/m}$$

Beam self weight = 24 x .3 x .23 = 1.66 kN/m

Rendering = 2(.3 + .23) x .025 x 20 = 0.53 kN/m

Total gk = 2.73 kN/m (see fig 6.1)

Live load, qk = 0.75 kN/m^2

x 3.6/2 = 1.35 kN/m

II. Floor Loading

Dead Load

150mmth Slab = .150 x 24 = 3.6 kN/m^2

finishes = 1.5 kN/m^2

partition = 1.8 kN/m^2

6.9 kN/m^2

gk1 = 6.9 x 3.6/2 = 12.24 kN/m

Beam self wt. 24 x .3 x .23 = 1.68 kN/m

Rendering = 2(.3 + .23) x .025 x 20 = 0.42

gk_2 = 2.08 kN/m

Total gk = 12.42 + 2.08

= 14.50 kN/m. (see fig. 6.1)

Live Load qk (required for residential flats) =1.5 kN/m^2

x 3.6/2 = 2.7 kN/m

6.1.2 Load for Section B/C

I. Roof Loading

Dead Load

Z-purlin & roofing sheets (say) = 0.3 kN/m^2

$= .3(\frac{4.1}{2} + \frac{3.6}{2})$ kN/m

= 1.115 kN/m

Beam Self Weight = 24 x.3 x .23 = 1.16 kN/m

Rendering = 2(.3 + .23) (.025 x 20) = 0.53 kN/m

Total gk = 3.345 kN/m (see fig 6.2)

Live Load qk = $.75\ (4.\frac{1}{2} + 3.\frac{6}{2})$

= 2.90 kN/m

II. Floor Loading

Dead Load

150mm th. Slab = .150 x 24 = 3.6 kN/m^2

Finishes = 1.5 kN/m^2

Partitions = 1.8 kN/m^2

Total g_{k1} = 6.9 kN/m

g_{k1} per m length = $6.9(\frac{4.1}{2} + \frac{3.6}{2})$ kN/m

= 26.498 kN/m

Beam Self wt. = 24 x .3 x .23 = 1.68 kN/m

Rendering = 2(.3 + .23) (.025 + 20) = 0.42 kN/m.

Total g_{k2} = 2.080

Total $g_k = g_{k1} + g_{k2}$ = 28.578 kN/m

(see fig.6.2)

Live Load $q_k = 1.5\ (\frac{4.1}{2} + \frac{3.6}{2})$ = 5.775 kN/m

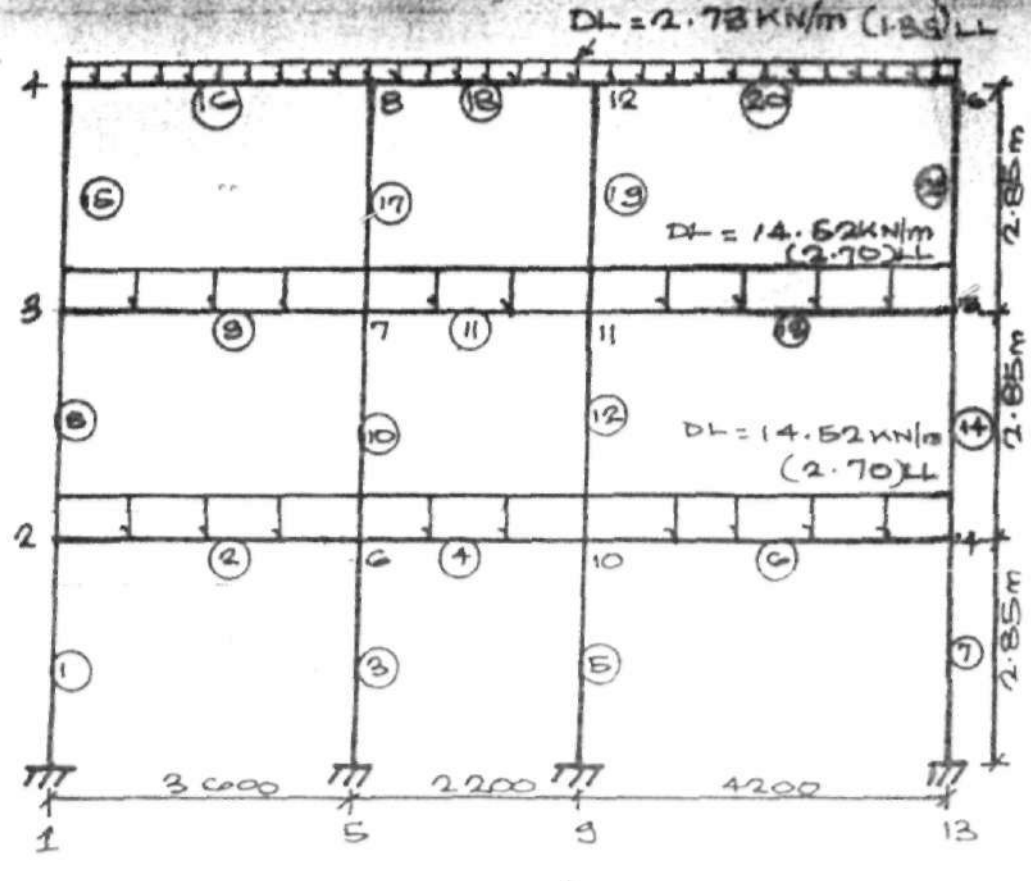


FIG.61: Loading at Section A/D

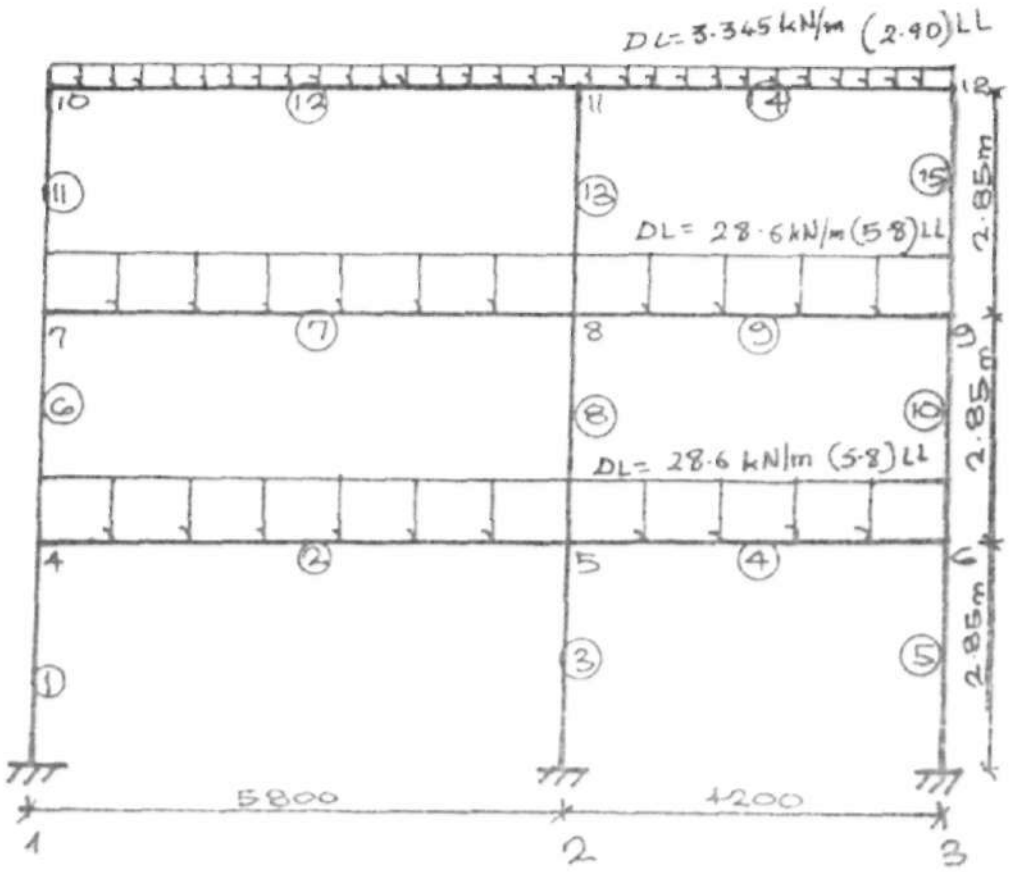
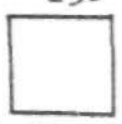
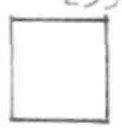
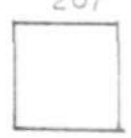
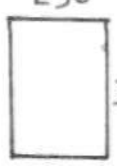


FIG.62: Loading at section B/C

DATA G05 ①		DATA G07 ① + 10% increase		DATA G09 ① + 25% increase	
1. Column					
 230 × 230	A=0.0529 I=.00023	 253 × 253	A = .064 I= .000341	 287 × 287	A= .0824 I= .0005
2. Beams (1st & IInd floor					
 230 × 450mm	A= .1025 I= .0017	 230 × 495	A =.1138 I=. 0023	 230 × 560	A=.1288 I=.0034
3. Beams at roof level					
 230 × 300	A=.069 I=.0005	 230 × 330	A=.0795 I=.0007	 230 × 315	A=.0862 I=.0010

Assuming that the dimension will not change much the dead load, all the dead **loads will remain** same in the both sections.

Table 6.1. Section Properties for Different Stiffnesses at Section A/D

For section B/D

DATA G06	DATA G08	DATA G10
1. As in Table -1	As in Table -1	As in Tatble -1
2. -do-	-do-	-do-
3. -do-	-do-	-do-

4.Column

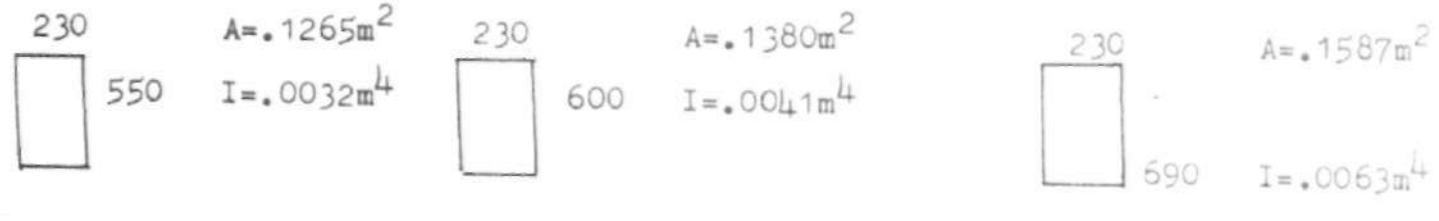


Table 6.2-1b Section Properties to Defferent Stittnesses at Section B/C

6.3 INTERPRETATION OF RESULTS OF ANALYSIS OF SCN GO5

(a) COMMENTS ON GLOBAL DISPLACEMENT OF SCN GO5 (see fig. 6.3)

1. All-ve x - movements show that the frame will sway to the left.
2. All-ve y - movements show that the frame will displace downward.
3. Some rotations are in the clockwise direction and some are in the anticlockwise direction.

(b) COMMENTS ON ELEMENT-END LOCAL FORCES OF SCN GO5 (see fig. 6.4 & 6.5)

1. All the beams have a little axial force.
2. All the columns have a little shear force.
3. The beams have shear forces and bending moments
4. The columns have axial forces and bending moments.

(c) COMPARISON OF ELEMENT END LOCAL FORCES GO5 (see fig. 6.5)

1. The maximum Axial Force will induce an column (5)
2. The maximum shear force will occur on element (6) at a-end.
3. The maximum-ve BM will occur on element (6) at a-end and on element (4) at b -end. i.e. the joint number (10) will be critical for bending moment.

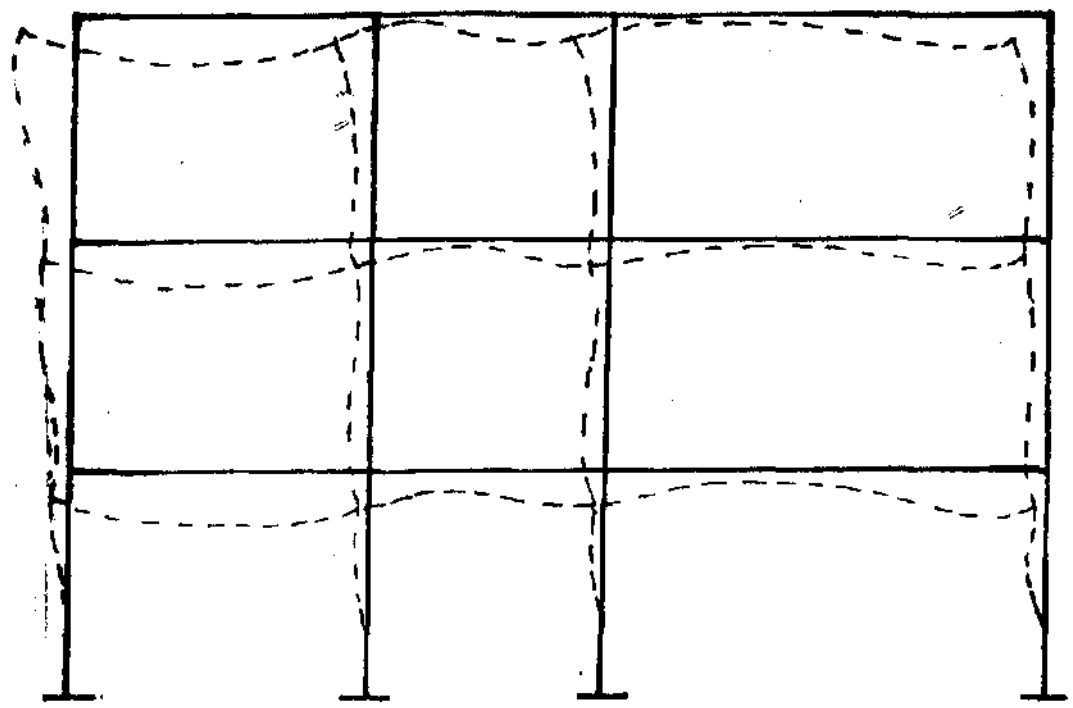


FIG.63: Deflected Shape Diagram for Load Combination 2 at Section A/D. G05

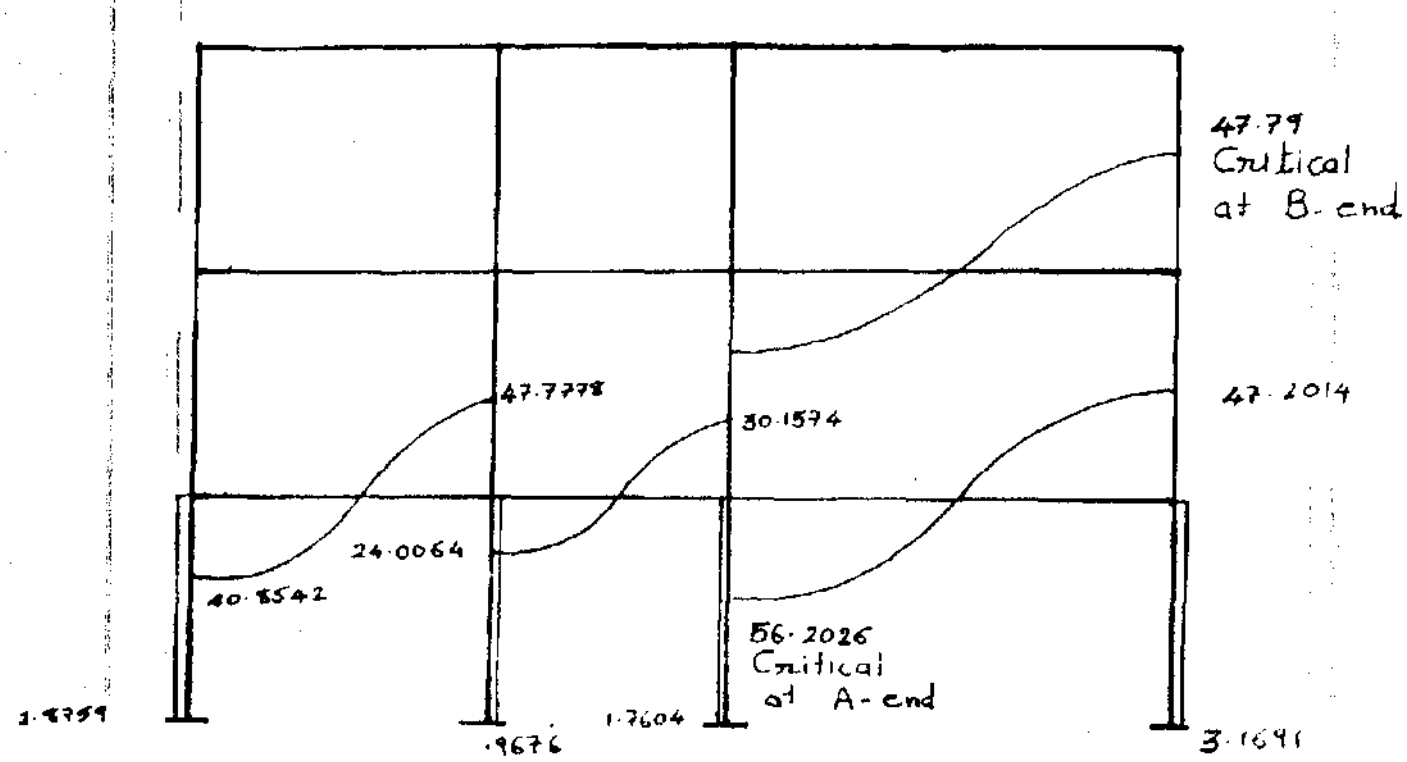


FIG.64: Shear Force Diagram for Load Combination 2 at Section A/D. G05

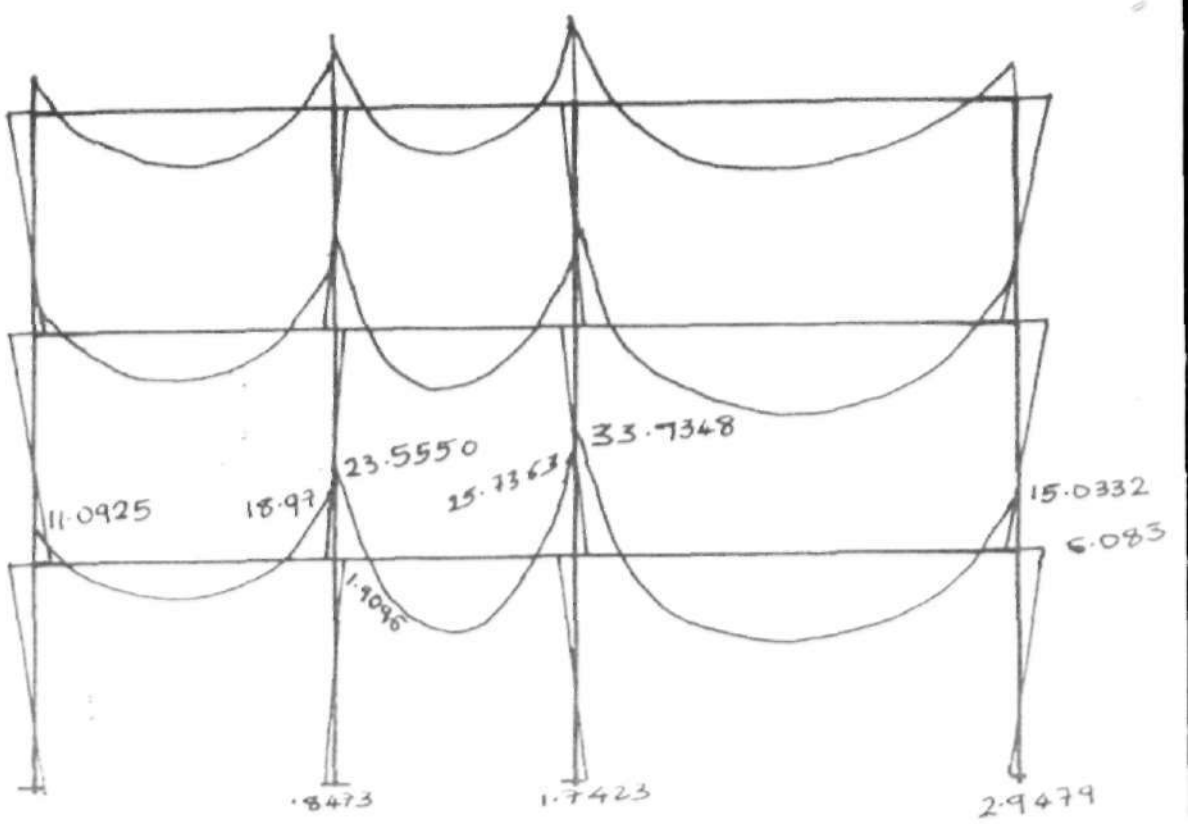


FIG. 6.5: Bending Moment Diagram for
Load Combination 2 at Section A/B COS

6.4 INTERPRETATION OF RESULTS OF ANLYSIS OF GO6

(a) GLOBAL JOINT DISPLACEMENT:

1. All-ve x - movements show that the frame will sway to the left.
2. All-ve y movements show that the frame will displace downward.
3. Some rotations are in the clockwise direction and some are in the anticlockwise direction.

(b) ELEMENT END LOCAL FORCES:

1. All the beams have a little axial force.
2. All the columns have a little shear force.
3. The beam have shear forces and bending moments
4. The columns have axial forces and bending moments.

(c) COMPARISON OF ELEMENT END LOCAL FORCES:

1. The max axial force will induce on column (3)
2. The max. shear force will occur on element (2) at b-end.
3. For the BM, Joint number (5) wii be critical.

6.5 CONMMENTS ON GLOBAL DISPLACEMENTS CONSIDERING DIFFERENT PARAMETERS UNDER SETTLEMENT.

The Table 6.3 depicts the results of global displacement at a particular joint under the external and internal support settlement. The percentage increase in each direction are calculated. We can see the undesirable effects of support settlement on displacement distributions. All the three displacements are increased substancially in either external or internal support settmement.

Further, the effects of external and internal support settlement on a particular joint is analysed (see Table 6.4)

	SCN	JN	LCM	X-MOVEMENT (mm)	% INCREASE	Y-MOVEMENT (mm)	% INCREASE	Z-ROTATION $x10^{-3}$ RAD	% INCREASE
A	G06	4	2	-.42		-.54		-2.58	
	G35	4	3	-1.82	433.1%	-19.90	3685%	3.18	223%
	G36	4	3	-1.27	302.0%	-.19	35.18%	-2.94	13.95%
B	G06	5	2	-.40		-.51		-.43	
	G35	5	3	-1.83	457.5%	-.0791	15.50%	1.24	388%
	G36	5	3	-1.23	207.5%	-19.78	3778%	.86	300%

TABLE6.3: COMPARISON OF GLOBAL DISPLACEMENTS IN 2 BAYS & 2 STOREYS FRAME STRUCTURE UNDER SUPPORT SETTLEMENT

SCN = Structure Code Number.

JN = Joint Number

LCM = Load Combination.

If 2, then under DL + LL

If 3, then under SS

DL = Dead Load.

LL = Live Load.

SS = Under Support Settlement Load

	SCN	JN	LCM	X-MOVEMENT (mm)	% INCREASE	Y-MOVEMENT (mm)	% INCREASE	Z-ROTATION $x10^{-3}$ RAD	% INCREASE
A	G05	14	2	-0.04		-.21		.69	
B	G31	14	3	2.36	(5900%)	-19.77	(9414%)	-4.48	(749%)
	G41	11	3	2.36	-	-19.86		-4.61	
	G51	8	3	2.53		19.92		-5.37	
C	G32	14	3	-1.0182		-.48		5.25	
	G42	11	3	-1.0220		-.30		5.658	
	G52	8	3	.40		-.19		7.57	

TABLE-64 COMPARISON OF GLOBAL DISPLACEMENTS IN 3 BAYS & 2 STOREYS FRAME UNDER EXTERNAL & INTERNAL SUPPORT SETTLEMENT AND CHANGE IN THE STOREYS.

(1) Here also we can see the undesirable effect of support settlement: (G05 & G31)

(2) The results in row (B) show that the variation in all x,y & z displacements distribution along the column line of settled support at a particular joint is not significant due to change in storeys.

(3) The results in row (C) show that the variation (decrease) in displacement distribution near the column line of SS at a particular joint is significant due to change in storey. As the storey reduces the displacements distribution reduces here: (G42 & G52).

6.6 COMMENTS ON FORCES UNDER SETTLEMENTS

Table 6.5 depicts the effect on forces considering different parameters under support settlement. The small 20 mm support settlement increases the forces significantly as shown in Table-6.5 and hence the stress level. Further, the effects on force distribution of different (external/internal) support settlement of 2 storeys frames are analysed. (see Table 6.6 & 6.7) The effects are found to be the same.

sCN	LCM	EE	NE	AXIAL FORCE kN	NE	SHEAR FORCE kN	NE EE	BENDING MOMENT kN-m
G05	2	a	3	161.3	4	24.00	6a	83.93
		b		-161.3		30.15	4b	-25.73
G31	3	a	3	-104.3	4	-58.41	6a	111.55 (328.8%)
		b		104.3		58.41(193%)	4b	-103.42 (402%)
G05	2	a	5	191.07	2	40.85		
		b		-191.07		47.77		
G32	3	a	5	225.44 (118%)	2	-67.02		
		b		-225.44 (118%)		67.02(140%)		

TABLE 6.5: COMPARISON OF ELEMENT END FORCES IN 3 BAYS 2 STOREYS FRAME UNDER EXTERNAL SUPPORT SETTLEMENT.

In the Table 6.6, the small 20mm external support settlement increases the forces significantly and hence the stress level. At different joint different force will become critical. In the Table 6.7, at different particular joint, different force will become critical.

SCN	LCM	NE	EE	AXIAL FORCE kN	NE	SHEAR FORCE kN	NE	BENDING MOMENT. kN-m
G06	2	3	a	639.18	9	128.18	9	115.31
			b	-639.18		83.54		- 19.46
G35	3	3	a	87.80	9	21.57(16.82%)	9	59.39(51.5%)
			b	- 87.80(13.74%)		- 21.57		39.24
G06	2	5	a	183.39	2	128.49	2	63.90
			b	-183.39		165.26		-170.52
G35	3	5	a	- 46.79(25.5%)	2	- 18.29	2	- 38.88
			b	46.79(25.5%)		18.29		- 67.23(39.4%)

TABLE 66 COMPARISON OF ELEMENT-END FORCES IN 2 BAYS & 2 STOREYS FRAME UNDER EXTERNAL SUPPORT SETTLEMENT

SCN	LCM	NE	EE	AXIAL FORCE kN	NE	SHEAR FORCE kN	NE	BENDING MOMENT kN-m
G06	2	3	a	639.18	7	129.33	7	66.83
			b	-639.18		164.43		-168.61
G36	3	3	a	-215.57	3	34.38	7	84.18(126%
			b	215.57		- 38.38		138.42
G06	2	4	a	183.39	4	129.54	4	115.78
			b	-183.39		83.54		- 19.44
G36	3	4	a	127.81(69.7%)	4	- 54.47	4	-152.66
			b	-127.81(69.7%)		54.47(65.2%)		

TABLE 67 COMPARISON OF ELEMENT END FORCES IN 2 BAYS 2 STOREYS FRAME UNDER INTERNAL SUPPORT SETTLEMENT.

6.7 EFFECTS OF EXTERNAL AND INTERNAL SUPPORT SETTLEMENT OF 3 BAYS AND 2 STOREY FRAME ON DISPLACEMENTS DISTRIBUTION.

In case of external support settlement, the sway (x-movement) along the particular column line has been more in comparison to internal SS. (see JN.5 & 6,SCN G.41 & 42).

In case of internal support settlement, the rotation al ong the particular column line has been more in comparison to external SS.

6.8 EFFECTS OF EXTERNAL AND INTERNAL SUPPORT SETTLEMENT OF 3 BAYS AND 1 STOREY FRAME ON FORCES DISTRIBUTION (SCN.G41 & G42)

The forces (x,y & z) are more in internal SS. (See SCN G41 & G42).

Similarly (See SCN G45 & G46.) the forces are more in internal SS.

*The comparison of results of G15 & G31 analysis show that greater the support settlement, greater the displacements and forces to be developed.

6.9.1 COMMENTS ON GLOBAL DISPLACEMENTS (D_y, D_x & D_z) of G31 (see fig. 6.6)

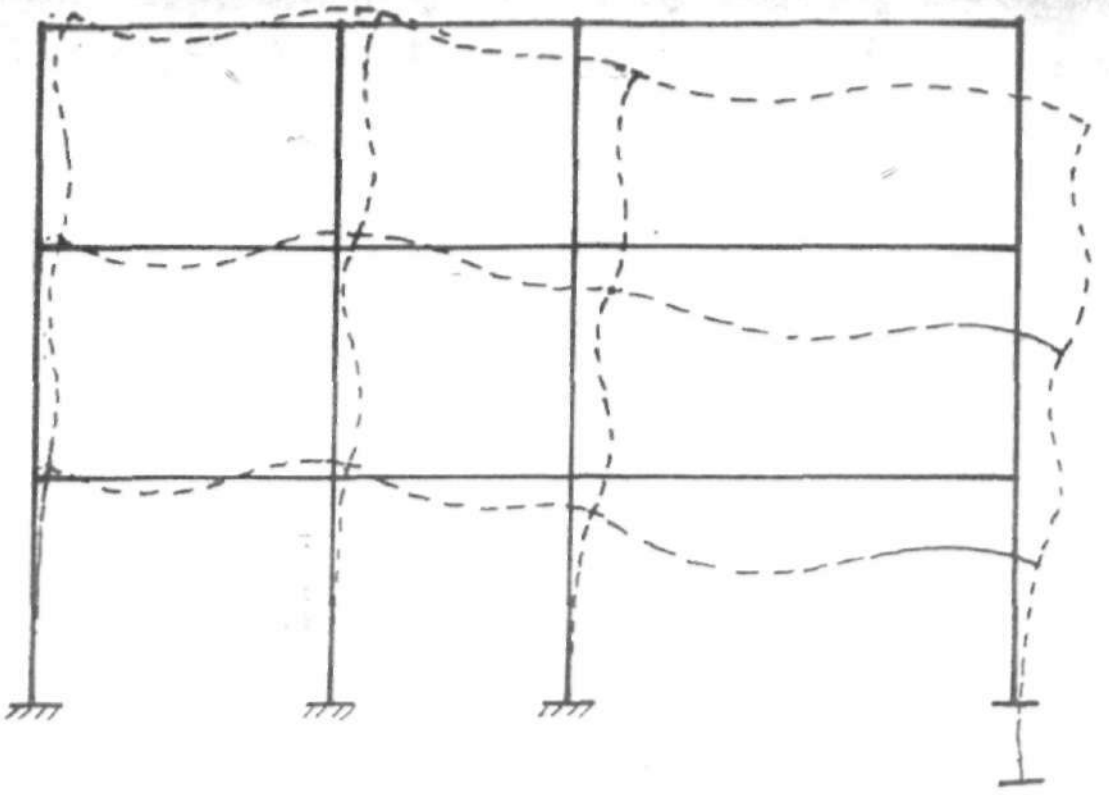
1. (Dy): The vertical displacement along the settled support vertical line are same as the support settlement i.e. very significant.
2. (Dx): The sway in the horizontal direction will be more for top members i.e. beams. and sway reduces from to to bottom.
3. (Dz): All the rotations arenegative, signifies the joint will rotate in the anti clockwise direction.

The rotations are maximum along the settled support line and reduces from bottom to top. The rotation reduces as moves far from settled support line.

6.9.2 COMMENTS ON GLOBAL DISPLACEMENTS: G32 (see fig 6.7)

1. Dy: The vertical displacements along the settled support vertical line are very significant or almost the same as support settlement.
2. Dx: The sways in the horizontal direction will be maximum for top members (i.e. beams) and sway in the vertical direction reduce from top to bottom.
3. Dz: The rotations along the settled support vertical line are negative.

The rotation along internal support vertical lines are negative. The rotation along external support vertical line are positive.



FIG·6·6: G31; Deflected Shape Diagram

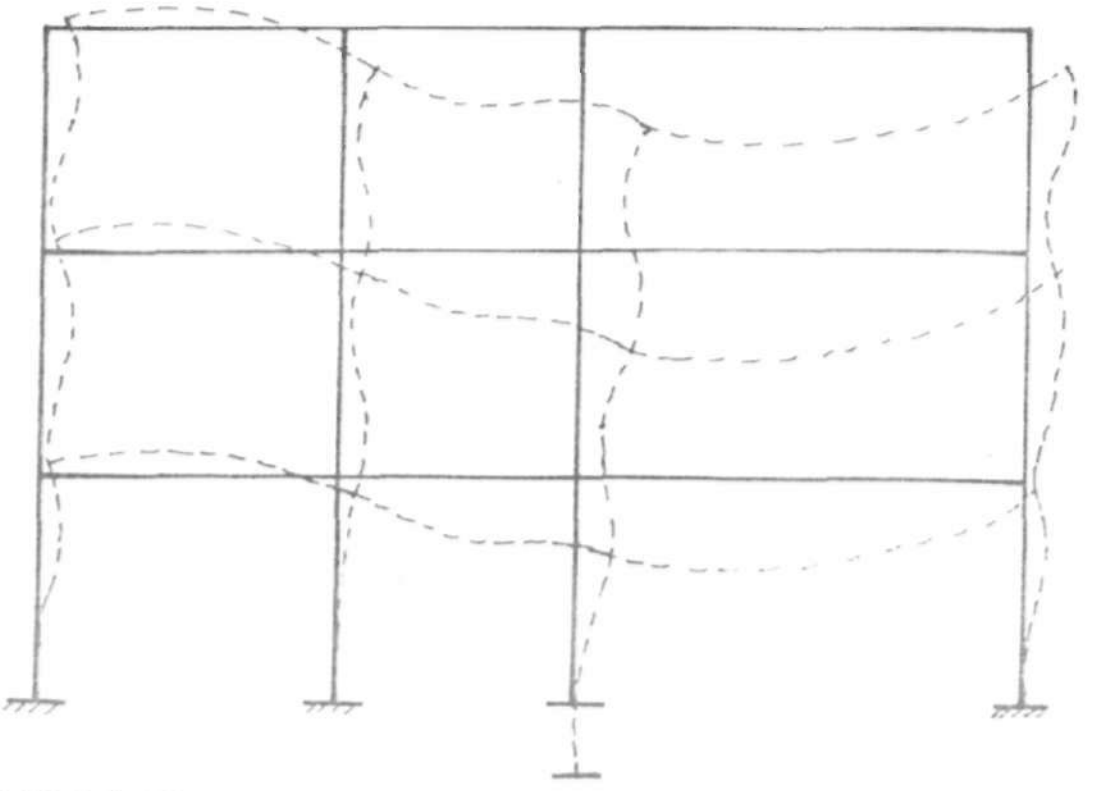


FIG.6·7:G32; Deflected Shape Diagram

6.9.3 COMPARISONS OF DISPLACEMENTS OF G31 & G32

DIRECTION	MAGNITUDE
1. Dy: Direction effects remain same in both G31 & G32.	Dy is more in G32 than in G31.
2. Dx: Directional effects remain same in both G31 & G32.	Dx is more in G31 than in G32.
3. Dz: All rotation are-ve in G31 where as internal rotation are -ve & external rotations are +ve in G32.	Dz is more in G32 than in G31.

6.9.4 DIFFERENTIAL SUPPORT SETTLEMENTS G33 (see fig. 6.8)

a. Global Displacements

1. Dy: The Dy along the internal settled support are more higher than the actual settled support.
2. Dx: All supports sway to the right. The magnitude of sway reduces for top to bottom.
3. Dz: All external rotations are anti clockwise positive while the internal rotation are clockwise -ve.

b. Element End Local Forces

We can see the most undesirable forces to be developed under differential support settlement.

1. The max. axial force will induce in column(3) as compression & column (5) as tension.
2. The maximum shear force will induce in Beam (1566kN) (4)
3. The joints (5) & (10) will become the most critical for bending moments.

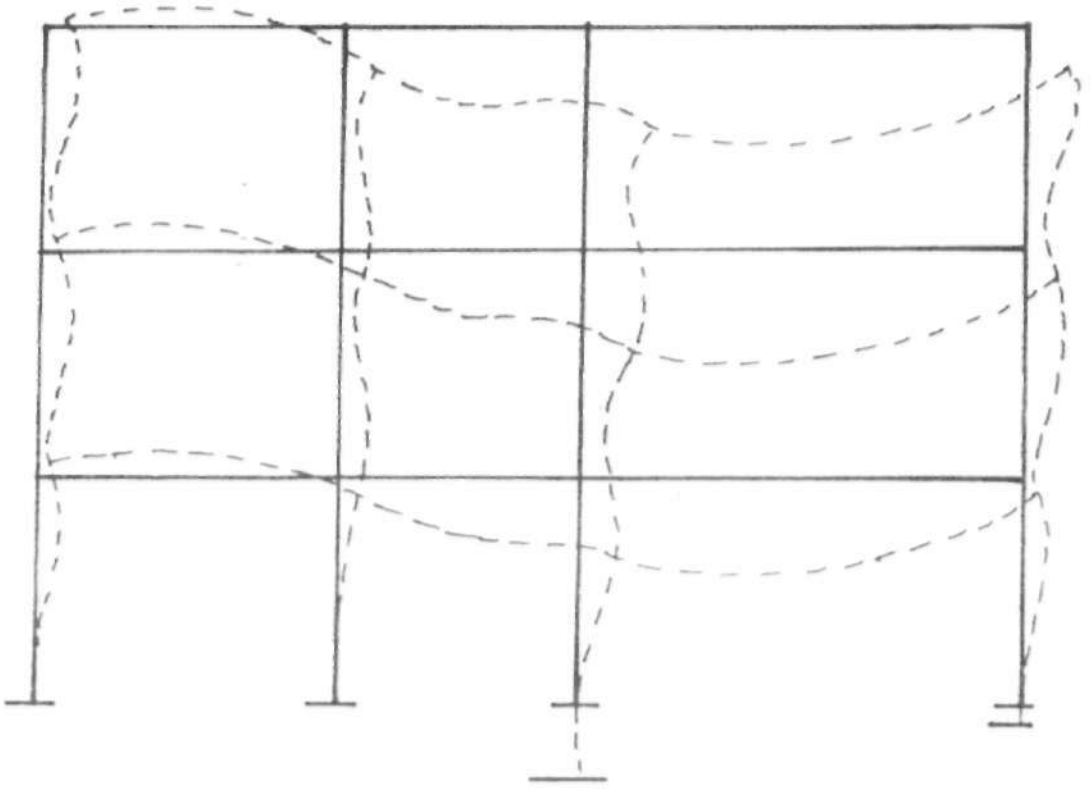


FIG.6·8 : G33; Deflected Shape Diagram

6.10 COMMENTS ON DISPLACEMENTS AND FORCES UNDER DIFFERENT STIFFNESSES

Table 6.8, as shown below, depicts the displacements and forces under different stiffnesses. The following factors have been considered here.

1. The displacement and forces are calculated for given cross sectional dimension of 3 bays frame structure shown in row(I)
2. The same as in (1) are calculated by 10% increasing the properties shown in row(II)
3. The same as in (1) are calculated by 25% increasing the sectional properties, shown in row(III)

In Table 6.8, the increase in sectional properties (i.e. stiffnesses results in the decrease of displacement or vice versa. The (%) increase in stiffness and corresponding (%) decrease in displacement at joint 16 of section A/D are calculated as shown in Table 6.9.

	SECTION PROPERTIES	LCM	GLOBAL DISPL. AT JOINT (16)			MAX/MIN. FORCES AT A-END		
			X-DISPL. (mm)	Y-DISPL. (mm)	Z-ROTATION $x10^{-3}$ RAD	AXIAL FORCE kN	SHEAR FORCE kN	BENDING MOMENT kN-m
I	Section Dimensions	1	-.1048	-.1943	.1564	109.88(5)	33.11(6)	20.01(6)
		2	-.1844	-.3453	.3767	191.07(5)	56.20(6)	33.93(6)
II	I + 10% Increase in Dimensions	1	-.0708	-.1617	.1074	109.20(5)	39.94(6)	19.87(6)
		2	-.1247	-.2873	.2602	189.89(6)	35.92(6)	33.70(6)
III	I + 25% Increase in Dimensions	1	-.0464	-.1260	.0754	108.87(5)	32.89(6)	19.72(6)
		2	-.0818	-.2238	.1819	189.31(5)	55.83(6)	33.44(6)

TABLE 6.8 COMPARISON OF DISPLACEMENTS AND FORCES FOR DIFFERENT MEMBER SIZES (OR STIFFNESSES) AND LOAD COMBINATIONS AT SECTION A/D.

SECTION PROPERTIES	LCM	GLOBAL DISPLACEMENTS AT JOINT 16					
		X-DISPL. (mm)	% DECREASE	Y-DISPL. (mm)	% DECREASE	Z-ROTATION $x10^{-3}$ RAD	% DECREASE
Given Section Dimensions	1	-0.1048	-	-0.1943	-	.1564	-
	2	-.1844	-	-.3453	-	.3767	-
1 + 10% Increase in Dimensions	1	-.0708	32.44%	-.1617	16.78%	.1074	31.33%
	2	-.1247	32.37%	-.1873	16.79%	.2602	30.93%
1+25% increase in dimensions	1	-.0464	55.73%	-.1260	35.15%	.0754	51.79%
	2	-.0818	55.64%	-.2238	35.19%	.1819	51.71%

TABLE-69 COMPARISON OF GLOBAL DISPLACEMENTS FOR DIFFERENT STIFFNESSES AND LOAD COMBINATIONS AT JOINT 16 OF SECTION A/D.

The 10% increase in the cross sectional dimensions (i.e. stiffness), in comparison to given section dimensions, results in 33% decrease in x-movement, 16% decrease in y-movement and 31% decrease in the z-rotation.

The 25% increase in the stiffness, incomparison to the given cross sectional properties, results in 55% decrease in the x-movement, 35% decrease in the y-movement and 51% decrease in z-rotation.

Similarly for the any given geometry and dimensions, the effect on displacement due to varing (different) stiffness can be calculated and easily compared.

As shown in Table 6.8 the overall increase in C/S dimensions will not significantly affect the forces distributions in the structure. But as discussed earlier, if the stiffness of a particular member is increased, the moment are more attracted to this member of the structure.

Now let us consider the same effect at section B/C of the structure. The results of analysis for a particular joint/member are shown in Table 6.10.

	SECTION PROPERTIES	LCM	GLOBAL DISPL. AT JOINT 10			MAX/MIN. FORCES		
			X-MOVEMENT (mm)	Y-MOVEMENT (mm)	Z-ROTATION $x10^{-3}$ RAD	AXIAL FORCE AT A-END kN	SHEAR FORCE AT B-END kN	MOMENT AT B-END kN-m
I	For Given C/S	DL	-1.0605	-.4901	-.0670	361.62(3)	96.49(2)	-99.56(2)
		LL	-1.8638	-.8939	-.6736	639.18(3)	165.29(2)	170.53(2)
II	(I)+10% Inc. in C/S	DL	-.6665 (37.15%)	-.40.78 (16.79%)	-.0364 (45.6%)	359.40(3)	95.93(2)	-98.80(2)
		LL	-1.1708	-.7937	-.4553	635.88(3)	164.30(2)	-168.17(2)
III	(I)+25% Inc. in C/S	DL	-.5120 (51.72%)	-.3175 (35.21%)	-.0262 (60.89%)	358.44(3)	95.92(2)	-98.28(2)
		LL	-.8982	-.5790	-.3152	633.59(3)	164.27(2)	-168.30(2)

TABLE 6.10 COMPARISON OF DISPLACEMENTS AND FORCES FOR DIFFERENT MEMBER SIZES (OR STIFFNESS) AND LOAD COMBINATIONS AT SECTION B/C

In the previous Table 6.8 the comparision of displacements and forces for 3 bay framed structure is shown, where as in Table 6.10 2 bay framed structure.

We can see the % decrease in displacements corresponding to % increase in stiffness are almost same except z-rotation.

6.11 COMMENTS ON STRESS LEVEL :. GO5

I. BENDING STRESS.

II. SHEAR STRESS.

I. Actual Bending Stress $6b = \frac{M.Y}{I}$

M = Moment due to loading

Y = Distance from neutral axis to top fibre.

I = Second moment of area

Consider Section A/D

Mmax = 33.93 kNm; I = 0017m4; $Y = \frac{450}{2} = 225m$

$6b = 33.93 \quad (.225/.0017) = 4.49 \ N/mm^2$

Permissible bending stress for M20 concrete

$fcr = 7.0 \ M/mm^2$ (Table-79 Renold & Steadman)

for M20

$6b < fcr \ .Ok$

II. 6v Shear stress = $\frac{VQ}{I.b}$

V= shear force at ULS

Q = first moment of inertia

I = second moment of inertia

b = breadth of beam.

or

6v av max. = 1.5 V/A = $\frac{1.5 \times 56.20}{.1025} = 822.4 KN/M^2$

$= .8224 \ N/mm^2$

For concrete grade M20 and 100 A_s/bd = .46, the permissible shear stress = .40 -.45N/mm^2

(CP - 110) (cl.3.3.6.1.)

The max shearing stress for M20 = 3.35 N/mm^2

.40 < fv (= .8224) < 3.35, hence O.K.

6.12 SATISFACTION OF CODE REQUIREMENTS FOR DEFLECTION

(Serviceability Limit State-SLS)

The SLS of deflection frequently controls many important dimensions in RC structures.

The principal controls upon section dimensions are those of strength. Strength are considered at the ultimate limite state.

Deflection: (cl.3.3.8, CP 110).

Excessive deflection may produce cracks in elements and finishes, discomforts to the users of the structure and adversely affect the appearance of the structure. It should be ensured that the deflections are not excessive. The result of this will frequently control the depth of section.

CP 110 adopts a simple approach based on limiting span/effective depth ratio given in tables 8 & 9 (CP 110).

Values of the span/effective depth ratio shown in table 8 & 9 (CP 110) are modified by factors for tension and compression reinforcement, shown in table 10 & 11 (CP 110).

$$\text{min. effective depth} = \frac{\text{Span}}{\text{Factor table 8 or 9 . Factor table 10 \& 11}}$$

The use of table 8 will restrict the deflection to approximately span/250.

Table - 8 span $\leq$ 10m

Table - 9 span $>$ 10m

SATISFACTION OF THE CODE REQUIREMENTS.

Serviceability Limit States for Deflections (cl.3.3.8, CP.110)

The L/d ratio

20 simply supported

26 continuous.

effective depth d = 425mm = 0.425

a. consider the section A/D

max length of the beam = 4.2m

for floor level beam $L/d = \frac{4.2}{0.425} = 9.88$

which is less than stipulated in code .Ok

for roof level beam $L/d = \frac{4.2}{.275} = 15.27$

Ok.

b. Consider the section B/D

maximum length of the beam 5.8m

for floor level beam $L/d = \frac{5.8}{.425} = 13.65$

Ok.

for roof level beam $L/d = \frac{5.8}{275} = 21.09$

Ok.

6.13 <u>Check for the Design for critical condition</u>: G05

$$M_x = 33.9348 - 56.0026x + 24.648\ x^2/2$$

$$\frac{dMx}{dx} = 0 \quad -56.2026 \quad + \quad 24.648 \times \frac{2x}{2}$$

for maximum condition (BM), $\frac{dMx}{dx} = 0$, hence, $x = 2.280m$

$$M_{max} = 33.9348 - 56.2026\ (2.28) + 24.648\ \left(\frac{2.28}{2}\right)^2$$

$= -30.1420$ KNm (a) 2.28m from end A

cover = 15 + 10 = 25mm

d = 450 - 25 = 425mm

$= .4\ fcu\ bd^2$

$= .4(20) \times .230\ (.425)^2$

$= .33235$

$\beta = M/.4\ fcu\ bd^2$

$= \frac{33.9348}{1000} \times .33285$

$= .1021$

$< .375$

$\alpha = 1 - \sqrt{1-2\beta}$

$= .1079$

$K = 4\ fcu\ /.87\ f\ y$

$= \frac{.4 \times 20}{.8 \times 230} = .04\ 347$

$\varrho = \alpha k = 0.0046$

$Ast = \varrho\ bd$

$= .0046 \times 230 \times 450$

$= 485.5\ mm^2$

provide 5 bars of 12mm diametre

Design of Column.

Max. axial force = 191.07KN

$$Asc = \frac{N - .35\ fcu\ bh}{.6\ fy}$$

$$= \frac{.19107 - .35x20x.23x.23}{.6 \times 230}$$

= -ve

provide 1% mm

$$A_{sc} = 0.01\ bh$$

$$= 0.01 \times 220 \times 230$$

$$= \underline{529mm^2}$$

(4 bars 16mm ϕ)

6.14 COMPUTING TIME

SCN	PF1	PF2	PF3	PF4	END	TOTAL TIME
G05	13.37.46	13.38.50	13.39.46	13.40.36	13.41.31	00.03.55
G06	13.41.31	13.42.16 13.43.43	13.43.02	13.44.22	13.45.18	00.03.47
G07	13.45.18	13.46.14	13.47.04	13.47.54	13.48.47	00.03.29
G08	13.48.47	13.49.33	13.50.08	13.50.46	13.51.27	00.03.56
G09	13.53.43	13.54.48	13.55.39	13.56.29	13.57.23	00.03.40
G10	13.57.23	13.58.08	13.58.48	13.59.26	14.00.08	00.02.45

TABLE - 11: Time Taken by IBM PC to Execute the Programs (PF1, PF2, PF3, & PF4).

The time depends on:

1. Number of elements
& 2. Number of load combinations.

Here, we can say the average range of time is 2-4 minutes to analyse the frame structure.

6.15 COMPUTING SCHEME

HARDWARE/SOFTWARE CONFIGURATIONS.

IBM PC 256 kb RAM

- System unit with two double sided 360kb Floppy disks drives
- Graphic card (640 x 200 pixels)
- High resolution screen (640 x 200 pixels)
- IBN PC Dos 20 operating system software.

IBM PC XT

- Same as above except one double sided 360kb Floppy disk drive and one fixed hard disk drive.

Loading the Program

Two Hoppy Disk Drive System

- system is on DOS is loaded
- place a formatted disk in drive A
- place a P-frame program disk in drive B
- Key in a B: P Frame<ENTER>
- if the following message appears cannot find A: BASRUN. EXE, Enter new drive letter.
- Key is B<ENTER>
- P frame will automatically loaded. You are ready to begin using the program when logo appears.

LOADING AND RUNNING THE PROGRAM

A FLOPPY AND HARD DISK DRIVE SYSTEM:

. System is on DOS is loaded.

. Place a formatted disk in Drive A

. Key in Assign B = C<ENTER>

. Key in B: PFRAME<ENTER>

. If the message can not find A; BASRUN: EXE Enter new drive letter:

. Key in C<ENTER>

* Ready.

CHAPTER - 7

CONCLUSIONS

Based on the results of analysis, the following conclusions have been made:

(1) The matrix displacement method and a direct spring model approach are presented in a form which make it suitable for the automatic computer analysis of any frame structure under different support settlements and stiffness variations. An efficient procedure is formulated and automated for assembly of element models into system models.

2. Ease and time saving can be obtained by this technique as it doesn't need to change the whole geometry as in the indirect approach.

(3) The external and internal support settlements of frame structures cause undesirable displacements and forces to be developed.

(4) The more likely cause of differential support settlements cause the most undesirable displacements and forces to be developed in rigid frame structures.

(5) Internal support settlement causes more forces than the external support settlements.

(6) The greater the support settlement the greater the displacement and forces to be developed.

(7) The change of stiffness of a member attracts more forces to that member.

(8) The overall change in the stiffness does not affect the force distributions. However, it does affect the displacement distributions.

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APPENDIX - I

USER'S GUIDE TO PROGRAM (PF)

Program PF is an engineering structural analysis program adopted (Abubakar, 1987) and modified specifically for IBM PC - microcomputer applications. The program is designed to analyse plane (two dimensional) frame structures under support settlement and stiffness variations. Several load cases and combinations may be specified. A load case includes element uniformly distributed loads, element point loads and joint loads.

The program utilizes the matrix displacement method of structural analysis. The computer formulates all necessary equations, solves them and stores the results. All data required by PF to generate and analyse a structure, is user-input via an input-data -file, created using either EDLIN text editor or any suitable word processor, such as word star. Categories of input data are given in section 5.3

Once the analysis is completed, PF will provide the results in an output file. Joint displacements (deflections and rotations) and element-end forces (axial, shear and bending moments) joint forces (applied and reactive) may be displayed numerously on the screen or printer. The numerical results output is formatted to allow a quick comparison of all displacements and forces created by each load combination, so that the most severe load combination on an element can quickly be obtained.

I.2 Program Capacity:

In addition PF has been designed to handle large frame structures through the efficient use of Random Access Memory (RAM). Using IBM PC with a minimum 256k RAM, PF will successfully execute problems with the following parameters:

Maximum No. of Elements	=	360
Maximum No. of Joints	=	200
Maximum No. of Supported Joints	=	60
Maximum No. of Material Section	=	50
Maximum No. of Load cases	=	10
Maximum No. of Load Combination	=	10
Maximum No. of Point Loads/elements		3
Maximum half-band width *system degree of freedom.	=	5500

I.3. PF

To use PF for frame structural analysis the engineer must begin by modelling the frame structures into data which can be recognised by the programme. Structural modelling is covered in section 3.2. Operation of the program involves (a) creating a data file with a name DATA. Gnn Where nn represent any two characters - structure number - used for identification;

(b) Keying in data into the file, in accordance to the formats (to be presented in INPUT DATA, section 1.5.) and

(c) Loading the program into the computer and executing the framed structural data. To load the program and execute, insert the PF system disk and type.

pf RETURN

The program will reply with:

Enter Data Disk Drive (A:,B:,C:),

Then type the appropriate data disk drive and RETURN.

Note that the program reads input data and writes input files in this drive.

Next, the program displays:

Enter structure Number (2 digits)

Now type the characters 'nn' used in creating the data file. Lastly, the program asks for the analysis disk drive (A:, B:, C:)

Note that only floppy disk drives are allowed for the analysis, since the programme utilizes Random Access Files.

I.4 UNITS

Any consistent units may be used. Note that the output headings are in KN, m and radians, hence it is recommended to use KN, m and radians as consistent units.

I.5 INPUT DATA

All data inputed are entered via either EDLIN (described in DOS reference manual) or any suitable word processor. The following sequence of data numerically defines the problem:

A. PROBLEM TITLE (A) - One line colums 1-50

Problem title to be printed with output.

B. JOINT COORDINATES

Refer to section (3.2.3) for detailed discussion on joint coordinates and numbering.

(i) Columns 1-5: option to generate the joint coordinates automatically. Enter 1 for automatic generation, else 0

(ii) Control information for automatic generation:

(2I5, 3E 10.0)

Enter the following if (1) is entered in (i) above

Columns: 1-5: Number of vertical columns

6-10 No. of horizontal members (Beams)

11-20 Span of the frame.

21-30 0

31-40 Spacing of vertical columns.

(iii) MANUAL JOINT COORDINATES DATA

If 0 is entered in (i) above, then enter:

(a) - No of joints - (I 5)

Columns 1-5: No. of joints:

(b) - Joint Data - (I5, 5 x, 2 E10.0, I5)

Columns - 1-5: Joint number.

11-20: X - coordinate

21-30: Y - coordinate

31-35: STEP (see not 1).

(c) EXIT - see note 2.

C. ELEMENT CONNECTIVITY AND SECTION PROPERTY NUMBER

Refer to sections (3.2.4. &3.2.5)for detail discussion on element connectivity and numbering.

(i) Columns 1 - 5: Option to generate element connectivity data automatically. Enter 1 for automatic generation else 0.

(ii) If 1 is entered in (i), then enter

(a) section property number for each element as follows (3I5):

Columns 1-5 : Element number

6-10: Section Property number

11-15: Step (see note 3) and

(b) EXIT (see note 2).

(iii) Else if 0 is entered in (i), then enter

a - Number of elements (I5)

b - Element connectivity data together with section Property number as follows (5I5):

Columns 1-5: Element number

6-10: A END joint number

11-15: B-END joint number

16-20: Section Property number

21-25: STEP (see note 3) and

(b) EXIT (see note 2).

D. JOINT RELEASES

Refer to Note 4 for detailed discussion on joint 'coding'. All joints degrees of freedom have been automatically set to code '0, 0, 0'. Hence, input data is required for only supported joints - (5I5):

Columns: 1-5: joint number

6-10: X - Movement

11-15: Y - Movement

16-20: Z - Rotation

21-25: STEP (See note 1)

EXIT (See note 2).

CAUTION: Remember to input the structure support joint degrees of freedom to '1' before running the program. This is to avoid rigid body translation that is, system stiffness martrix singularity.

E. SPRING STIFFNESSES

(i) Number of joint loaded with springs

(ii) For each joint, enter spring stiffness

(I5,3E 10.0)

Columns: 1-5: Loaded joint number

6-15: Stiffness in X - direction KN/M

16-25: Stiffness in Y - direction KN/M

26-30: Stiffness in Z - direction (KN/M-rad).

Exit

F. MATERIAL PROPERTIES

(i) Control information (I5, 5x, 2E 10.0)

Columns 1-5: Number of sections. This refers to the total number of different elements sections used in the frame

11-20: Elasticity Modulus.

(ii) Element Property Data - (2E10.0)

Columns: 1-10: Area of section

11-20: Moment of Inertia

Repeat (ii) as many times as there are number of sections specified in (i) above.

G. LOADINGS

Refer to chapter 6 for detailed calculation on frame strudue loadings.

(a) Loading Information - (2I5)

Columns:

1-5: Number of load cases

6-10: Number of load combinations.

Enter the following sets of data for each load case

(b) Load case title - (A)

Columns 1-50 Load case title

b—I Uniformly distributed load data (I5, 3E 10.0, I5)

Columns:

1-5: Element number, on which this load is applied.

6-15: Value of applied load per unit length.

16-25: Starting distance of applied load from 'a-end' of the element.

26-35: Distance of the finishing point of applied load with respect to 'a-end'. Enter 0 to assume the whole length of the element.

36-40 STEP (See note 3).

EXIT (See note 2).

b-II Element point loads Data - (I5, 6E10.0, I5)

A maximum of three point loads are permissible per element. Element point loads are located from the lower joint number (a-end) relative to the local coordinate axis.

Columns: 1-5: Element number on which this load is applied

6-15: Value of applied concentrated load 1

16-25: Distance of applied load 1 from 'a-end'

26-35: Value of applied concentrated load 2

36-45: Distance of applied load 2 from 'a-end'

46-55: Value of applied concentrated load 3

56-65: Distance of applied load 3 from 'a-end'

66-70: STEP (See note 3).

EXIT (See note 2).

b - III Joint load Data -(I5, 3E 10.0, I5)

Refer to section 5.3.2. for a discussion of joint load coding.

Columns:

1-5: Joint number at which this set of load is applied.

6-15: Applied force about global X-axis.

16-25: Applied force in global Y-axis.

26-35: Applied moment about global Z-axis.

36-40: STEP (See note 4).

EXIT (See note 2).

H. OUTPUT INFORMATION

Output information consists of the load combination data and particular joints and elements of which results are desired:

(a) Load combination Data

(i) Load combination title - A

Columns 1-50: Load combination title

(ii) Load Combination Factors - For each required load case, (I5, E 10.0):

Columns 1-5: Load case number

6-15: Load factor for this loadcase.

Repeat (ii) for all load cases required in this load combination. Data is required for only the combined load cases.

TO EXIT to the next load combination either enter 0 as a response to load case number or leave a blank line.

Repeat the above procedure from (i) as many times as there are number of load combinations.

(b) To output results concerning particular joints or elements, enter the information as follows:

(i) Title - (A)

Columns: 1-50: Title of response to be printed with output. See next page.

(ii) Concerned Joints/Elements Data - (3I5)

Columns: 1-5: Start joint/Element number

6-10: Finish joint/Element number

11-15: STEP.

That is, to output results of start-joint or element number through finish-joint or element number at step specified, for all load combinations. To EXIT to the next

response either enter zero on column 5 or leave a blank line.

Title response refers to are of the followings:

- Global Joint Displacements.
- Element-End Local Displacements.
- Element-and Forces.
- Support Reactions and
- Element End Forces Comparison.

Repeat the above procedure from (i) for each of the above titles.

NOTES:

1 - Usually, one line is needed for each joint. This can be achieved by setting step less than or equal to zero However, if some joints fall in a straight line and are equidistant, then data for only the first and the last joints of this group are needed.

Intermediate joint coordinates are automatically generated by linear interpolation. Step gives the constant increament from a joint to its neighbouring joint number. A second line is needed for the last joint. FORMAT of this line is (I5, 5x, 2E 10.0):

Columns: 1-5: Joint number
11-20: X-coordinate
21-30: Y-coordinate.

In the case of Joint releases and joint load data, if some joints are on a line in such a way that the difference between the joint number is constant, then

STEP gives this constant for automatic generation. Joint number of the last joint in this group must be given on the next line (I5).

Columns 1-5: Joint number.

2. EXIT - To signal the completi on of any set of data in which EXIT has been indicated, enter zero as a response to joint/element number or leave a blank line. Failure to do so may lead to FATAL errors.

3. Usually, one line is needed for each element by setting STEP less or equal to zero. However, if some elements are on a line in such a way that the numerical difference between their connecting joint pairs is constant, then, only the data for the first element as that line need be input. STEP gives this constant for automatic generation. In addition, data for the last element on this line must be entered on the next line. (I5).

Columns: 1-5: Element number.

4. Joint Coding

Frame joints can be allowed to rotate in the global 'Z' direction as well as displacement along 'X' and 'Y' directions.

A joint code consist of a three digit number. The first digit specifies possible displacement along X axis. The second digit specifies possible displacement

in the Y - axis and the third digit specifies possible rotation about Z- directions.

'0' indicates the joint is free to move in that direction.

'1' indicate the joint is 'fixed' and is not allowed to move in that direction.

Example:

APPENDIX - II

Varification Examples

Ex-1 A propped cantilever (see fig - A. II.1) (william,1978)

Given

$A = 0.000853 m^2$

$I = 0.1066 \times 10^{-6} m^4$

$E = 210E6\ KN/m^2$

Solution: $\alpha = EI/L^3 = \dfrac{210E6 \times 0.1066E-6}{(5.0)^3} = 0.18$

$Ky = \dfrac{AE}{L} \times 10 = \dfrac{0.000853 \times 210E6}{5.0} \times 10 = 358\ 260\ KN/m$

1. Unknowns q1 & q2
2. Element models: $f = kd + \hat{f}$
3. System model: $Kq + Ksq = Q + Qs$

where Ks is system spring stiffness matrix; Qs is system spring force matrix

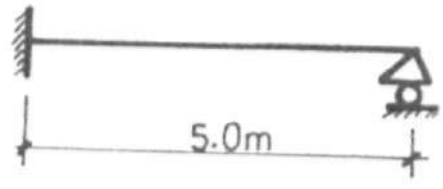
N.B. while assembling the structure, consider the contribution of force due to spring modeling.

M = (0, 0, 1, 2

since local and global axis coinside with each other λ will be unit matrix.

$$K = \sum Kg \xleftarrow{M} K \Leftarrow \lambda^T k \lambda . \quad k = \begin{matrix} \\ 0 \\ 0 \\ 1 \\ 2 \end{matrix} \begin{matrix} \begin{matrix} 0 & 0 & 1 & 2 \end{matrix} \\ \begin{bmatrix} 12 & 6L & -12 & 6L \\ 6L & 4L^2 & -6L & 2L^2 \\ -12 & -6L & 12 & -6L \\ 6L & 2L^2 & -6L & 4L^2 \end{bmatrix} \end{matrix}$$

$$K = \begin{matrix} \\ \alpha \end{matrix} \begin{matrix} \\ \begin{bmatrix} 12 & -6L \\ -6L & 4L^2 \end{bmatrix} \end{matrix}$$



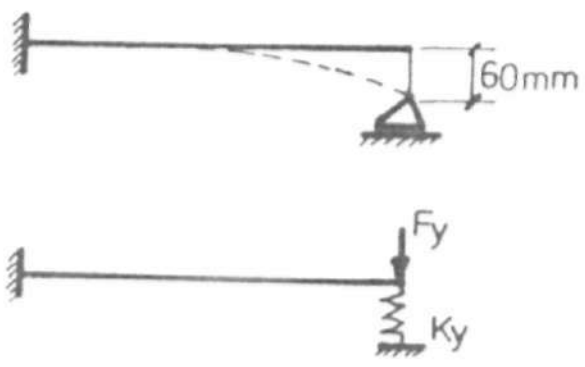


FIG.A.II.1 Verification Example: A Propped Cantilever.

$$K_s = \begin{matrix} 0 & 0 & 1 & 2 \end{matrix}$$

$$\begin{bmatrix} K_y & & & \\ & K_z & & \\ & & K_y & \\ & & & K_z \end{bmatrix} \begin{matrix} 0 \\ 0 \\ 1 \\ 2 \end{matrix} = \begin{bmatrix} K_y & 0 \\ 0 & K_z \end{bmatrix}$$

$$K.q + K_s q = Q + Q_s \quad \text{where } Q = \bar{Q} - \hat{Q}$$

since $\bar{Q}$ and $\hat{Q}$ are zero,

$$Q = 0$$

$$\alpha \begin{bmatrix} 12 & -6L \\ -6L & 4L^2 \end{bmatrix} \begin{bmatrix} q1 \\ q2 \end{bmatrix} + \begin{bmatrix} K_y & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} q1 \\ q2 \end{bmatrix} = \begin{bmatrix} -F_s \\ 0 \end{bmatrix}$$

$$\alpha (12q1 \quad -6Lq2) \quad + \quad K_y \cdot q1 \quad = \quad -F_s \qquad (1)$$

$$\& \quad \alpha (-6L\ q1 \ + 4L^2 q2) \quad + \quad 0 \quad = \quad 0 \qquad (2)$$

from (2)

$$q2 = + \frac{3}{2L} q1 \qquad (3)$$

Substituting (3) in (1)

$$\alpha\left[12\ q1 \ - 6L \ \left(\frac{3}{2L}\ q1\right)\right] + K_y q1 = -F_s$$

$$\alpha(3q1) \quad + \quad K_y\ q1 \quad = \quad -F_s$$

$$(3\alpha + K_y) \quad q1 \quad = \quad -F_s$$

$$q1 = - \frac{F_s}{3\alpha + K_y}$$

$$= - \frac{21\ 495.6}{3x0.18 + 358\ 260}$$

$$= - 0.05999m$$

$$q2 = 3/2L(q1) = \frac{3}{2 \text{ x } 5.0} \text{ x } (-0.05999)$$

$$= - 0.01799 \text{ (rad)}.$$

q1 - 0.05999m

q2 - 0.01799. Ans.

Element End Forces.

$$f = kd + \hat{f} \qquad \text{where } \hat{f} = 0 \text{ and}$$

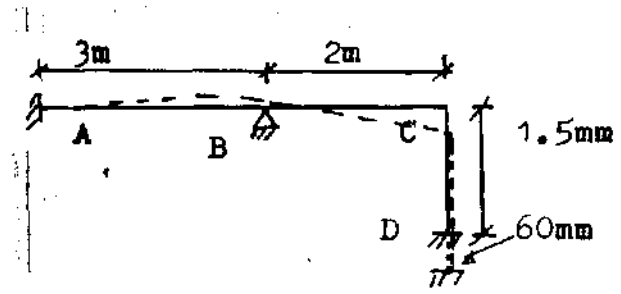
$$\therefore f = \alpha \begin{bmatrix} -12 & 6L \\ -6L & 3L^2 \\ 12 & -6L \\ 6L & 4L^2 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ q1 \\ q2 \end{bmatrix} \qquad d = \begin{bmatrix} 0 \\ 0 \\ q1 \\ q2 \end{bmatrix} \begin{matrix} 0 \\ 0 \\ 1 \\ 2 \end{matrix}$$

$$= \alpha \begin{bmatrix} -12q1 + 6L\ q2 \\ -6Lq1 + 2L^2\ q2 \\ 12q1 - 6L\ q2 \\ 6Lq1 + 4L^2\ q2 \end{bmatrix}$$

$$f = \begin{bmatrix} + 0.0329 \\ + 0.1620 \\ - 0.0324 \\ + 0.0000 \end{bmatrix} \text{ Ans.}$$

Example 2 (Majid, 1980)

The foundation D in the frame shown in figure (A.II.2) subsides vertically by 60mm. calculate moment induced in the frame.



$EI = 2x10^6$ KN-mm throughout

Stiffness Distribution Factor

Joint	Member	k	Total K	Distribution Factor
	BA	I/3	5I/6	2/5
B	BC	I/2		3/5
	CB	I/2	7I/6	3/2
C	CD	I/1.5		4/7

The settlement of D to D' makes C subsides by 60mm. The forced end moment due to the sway in BC without rotation is $6EI\delta/L^2$ which is 6 EI x $60/2000^2$ = 360 EI/ 4000 000. A fixed end moment of 360 KN.mm acting at BC and CB are distributed as shown here. The resulting moments are then multiplying by EI/4e6.

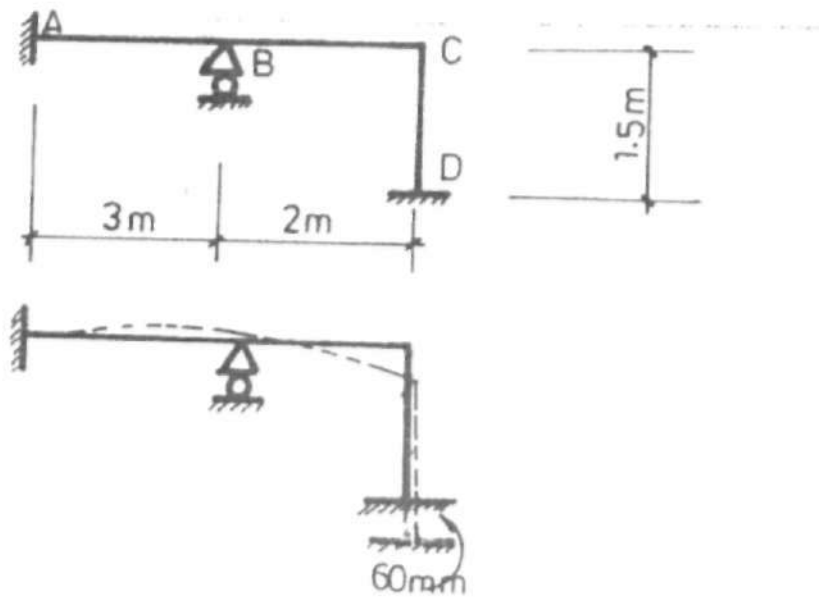


FIG.A.II.2 Verification Example: A simple Frame

Moment Distribution

Joint	A	B		C	D
Member	AB	BA	BC	CB	CD	DC
D.F.		2/5	3/5	3/7	4/7	
FEM			360	360		
RelapB		-144	-216			
C.O.at(A)&(C)	-72			-108		
Relexc C				-108	-144	
			-54			72
		22	32			
	11			16		
			7	9		
		-4			-5	
	2		2			
	1			1		
				0	-1	
						-1
Total $\underline{t}$	-60	-120	120	154	-154	-78
Final Moment = tEI/4e6	-30	-60	60	77	-77	-39

Answers.
KN.mm

STRUCTURAL ANALYSIS OF PLANE FRAMES

STRUCTURE NO. 01 EXAMPLE Q.2. (Departmental M.Sc. Exam, 1987)

CONTROL INFORMATION

NO. OF ELEMENTS	=	3
NO. OF JOINTS	=	4
NO. OF LOAD CASES	=	1
NO. OF LOAD COMBINATIONS	=	1

GENERAL DATA

ELASTICITY MODULUS = .2100E+09

JOINT DATA

JOINT NO.	X-FREEDOM	Y-FREEDOM	Z-FREEDOM	X-COORDINATE (METRES)	Y-COORDINATE (METRES)
1 S	1	1	1	.0000	.0000
2	0	0	0	.0000	20.0000
3	0	0	0	20.0000	20.0000
4 S	1	1	1	40.0000	.0000

ELEMENT DATA

Section Property Data :

SECTION NUMBER	SECTION AREA (M4)	MOM. INERTIA (M4)
1	.0494	.0005

Element Connectivity Data :

ELEMENT NUMBER	LOWER JOINT	GREATER JOINT	SECTION NUMBER	ELEMENT LENGTH
1	1	2	1	20.0000
2	2	3	1	20.0000
3	3	4	1	28.2843

LOAD DATA

LOAD CASE 1 POINT LOAD ON MEMBER 2

Element Uniform Load :

ELEMENT NUMBER	UNIFORM LOAD (KN/m)	DISTANCE FROM A-END START (m)	END (m)

Element Point Loads

ELEMENT NUMBER	PT. LOAD 1 (KN)	DIST. (M)	PT. LOAD 2 (KN)	DIST. (M)	PT. LOAD 3 (KN)	DIST. (M)
2	-10.000	10.000	.000	.000	.000	.000

Joint Loads

LOADED JOINT	HORIZONTAL LOAD-X (KN)	VERTICAL LOAD-Y (KN)	EXTERNAL MOM.-Z (KN-m)

```
  LOAD COMBINATION DATA

        LOAD COMBINATION NO./FACTORS
  LC     1
   1    1.00



  LOAD COMBINATION      1     LOAD COMBINATION ONE
  ------------------------------------------------------------------------


  OUTPUT INFORMATION

GLOBAL JOINT DISP
   1     4     1
MEMBER-END DISP
   1     3     1
MEMBER-END FORCES
   1     3     1
SUPPORT REACTIONS
   1     2     1
COMPARE
   1     3     1
  ------------------------------------------------------------------------

  SYSTEM DEGREES-OF-FREEDOM    =     6
  BAND-WIDTH                   =     6
  NO. OF SUPPORTED JOINTS      =     2

  ------------------------------------------------------------------------
```

GLOBAL DISPLACEMENTS

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
1	1	.0000	.0000	.0000
2	1	11.9667	.0129	.8732
3	1	11.9724	11.9895	-.8697
4	1	.0000	.0000	.0000

ELEMENT - END DISPLACEMENTS

ELEMENT NUMBER	LOAD COMB.	JOINT NO.	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad
1	1	1	.0000	.0000	.0000
		2	.0129	-11.9667	.8732
2	1	2	11.9667	.0129	.8732
		3	11.9724	11.9895	-.8697
3	1	3	-.0120	16.9436	-.8697
		4	.0000	.0000	.0000

ELEMENT - END FORCES

ELEMENT NUMBER	LOAD COMB.	JOINT NO.	AXIAL - X KN	SHEAR - Y KN	MOMENT - Z KN - m
1	1	1	-6.7080	2.9606	25.4430
		2	6.7080	-2.9606	33.7698
2	1	2	-2.9602	-6.7080	-33.7698
		3	2.9602	-3.2920	-.3894
3	1	3	-4.4211	.2349	.3894
		4	4.4211	-.2349	6.2534

SUPPORT REACTIONS

JOINT NO.	LOAD COMBINATION	FORCE - X KN	FORCE - Y KN	MOMENT - Z KN - m
1	1	-2.9606	-6.7080	25.4430

STRUCTURAL ANALYSIS OF PLANE FRAMES

STRUCTURE NO. 21 Simple Plane frame With Support Settlement

(Majid, 1980)

CONTROL INFORMATION

NO. OF ELEMENTS	=	3
NO. OF JOINTS	=	4
NO. OF SPRINGS	=	1
NO. OF LOAD CASES	=	1
NO. OF LOAD COMBINATIONS	=	1

GENERAL DATA

ELASTICITY MODULUS = .2000E+09

JOINT DATA

JOINT NO.	X-FREEDOM	Y-FREEDOM	Z-FREEDOM	X-COORDINATE (METRES)	Y-COORDINATE (METRES)
1 S	1	1	1	.0000	.0000
2 S	0	1	0	3.0000	.0000
3	0	0	0	5.0000	.0000
4 S	1	0	1	5.0000	-1.5000

ELEMENT DATA

Section Property Data :

SECTION NUMBER	SECTION AREA (M2)	MOM. INERTIA (M4)
1	.000109540	.000000010

SPRING STIFFNESSES

LOADED JOINT	X - DIRECTION KN/m	Y - DIRECTION KN/m	Z - DIRECTION KN-M/rad.
4	.0000	146053.3000	.0000

Element Connectivity Data :

ELEMENT NUMBER	LOWER JOINT	GREATER JOINT	SECTION NUMBER	ELEMENT LENGTH
1	1	2	1	3.0000
2	2	3	1	2.0000
3	3	4	1	1.5000

LOAD DATA

LOAD CASE 1 Joint loads

Element Uniform Load :

ELEMENT NUMBER	UNIFORM LOAD (KN/m)	DISTANCE FROM A-END START (m)	END (m)

Element Point Loads

ELEMENT NUMBER	PT. LOAD 1 (KN)	DIST. (M)	PT. LOAD 2 (KN)	DIST. (M)	PT. LOAD 3 (KN)	DIST. (M)

Joint Loads

LOADED JOINT	HORIZONTAL LOAD-X (KN)	VERTICAL LOAD-Y (KN)	EXTERNAL MOM.-Z (KN-m)
4	.0000	-8763.2000	.0000

```
   LOAD COMBINATION DATA

         LOAD COMBINATION NO./FACTORS
   LC     1
    1    1.00



   LOAD COMBINATION      1        Load combination one
   ------------------------------------------------------------------------------


   OUTPUT INFORMATION

 Global joint displacements
      1     4     1
 Element-End local displacements
      1     3     1
 Element-end forces
      1     3     1
 Support reactions
      1     2     1
      4     4     1
 Element-End forces
      1     3     1
   ------------------------------------------------------------------------------

   SYSTEM DEGREES-OF-FREEDOM    =     6
   BAND-WIDTH                   =     6
   NO. OF SUPPORTED JOINTS      =     3

   ------------------------------------------------------------------------------
```

GLOBAL DISPLACEMENTS

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
1	1	.0000	.0000	.0000
2	1	.0105	.0000	-22.6666
3	1	.0175	-59.9948	-14.4370
4	1	.0000	-59.9995	.0000

ELEMENT - END DISPLACEMENTS

ELEMENT NUMBER	LOAD COMB.	JOINT NO.	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad
1	1	1	.0000	.0000	.0000
		2	.0105	.0000	-22.6666
2	1	2	.0105	.0000	-22.6666
		3	.0175	-59.9948	-14.4370
3	1	3	59.9948	.0175	-14.4370
		4	59.9995	.0000	.0000

ELEMENT - END FORCES

ELEMENT NUMBER	LOAD COMB.	JOINT NO.	AXIAL - X KN	SHEAR - Y KN	MOMENT - Z KN - m
1	1	1	-.0769	-.0302	-.0302
		2	.0769	.0302	-.0604
2	1	2	-.0769	.0687	.0604
		3	.0769	-.0687	.0767
3	1	3	-.0687	-.0769	-.0769
		4	.0687	.0769	-.0384

SUPPORT REACTIONS

JOINT NO.	LOAD COMBINATION	FORCE - X KN	FORCE - Y KN	MOMENT - Z KN - m
1	1	-.0769	-.0302	-.0302
2	1	.0000	.0989	.0000

JOINT NO.	LOAD COMBINATION	FORCE - X KN	FORCE - Y KN	MOMENT - Z KN - m
4	1	.0769	-.0687	-.0384

COMPARISON OF ELEMENT-END FORCES

COMPARISON OF FORCES ALONG ELEMENTS 1 THRU 3 AT STEP 1

LOAD COMB	ELEM END	Max/Min AXIAL - X	On EL.	Max/Min SHEAR - Y	On EL.	Max/Min MOMENT - Z	On EL.
1	A-End	-.07	3	.07	2	.06	2
		-.08	1	-.08	3	-.08	3
	B-End	.08	1	.08	3	.08	2
		.07	3	-.07	2	-.06	1

STRUCTURAL ANALYSIS OF PLANE FRAMES

STRUCTURE NO. 22 Simple Beam With Joint Forces **(William, 1978)**

CONTROL INFORMATION

NO. OF ELEMENTS	=	1
NO. OF JOINTS	=	2
NO. OF SPRINGS	=	1
NO. OF LOAD CASES	=	1
NO. OF LOAD COMBINATIONS	=	1

GENERAL DATA

ELASTICITY MODULUS = .2100E+09

JOINT DATA

JOINT NO.		X-FREEDOM	Y-FREEDOM	Z-FREEDOM	X-COORDINATE (METRES)	Y-COORDINATE (METRES)
1	S	1	1	1	.0000	.0000
2		0	0	0	5.0000	.0000

ELEMENT DATA

Section Property Data :

SECTION NUMBER	SECTION AREA (M2)	MOM. INERTIA (M4)
1	.000853000	.000000106

SPRING STIFFNESSES

LOADED JOINT	X - DIRECTION KN/m	Y - DIRECTION KN/m	Z - DIRECTION KN-M/rad.
2	.0000	358260.0000	.0000

Element Connectivity Data :

ELEMENT NUMBER	LOWER JOINT	GREATER JOINT	SECTION NUMBER	ELEMENT LENGTH
1	1	2	1	5.0000

LOAD DATA—

LOAD CASE 1 Joint loads

Element Uniform Load :

ELEMENT NUMBER	UNIFORM LOAD (KN/m)	DISTANCE FROM A-END START (m)	END (m)

Element Point Loads .

ELEMENT NUMBER	PT. LOAD 1 (KN)	DIST. (M)	PT. LOAD 2 (KN)	DIST. (M)	PT. LOAD 3 (KN)	DIST. (M)

Joint Loads

LOADED JOINT	HORIZONTAL LOAD-X (KN)	VERTICAL LOAD-Y (KN)	EXTERNAL MOM.-Z (KN-m)
2	.0000	-21495.6000	.0000

```
   LOAD COMBINATION DATA

         LOAD COMBINATION NO./FACTORS
   LC     1
    1    1.00



   LOAD COMBINATION      1        Load combination one
   ------------------------------------------------------------------------------


   OUTPUT INFORMATION

 Global joint displacements
     1     2     1
 Element-End local displacements
     1     1     1
 Element-end forces
     1     1     1
 Support reactions
     1     2     1
 Element-End forces
     1     1     1
   ------------------------------------------------------------------------------

   SYSTEM DEGREES-OF-FREEDOM    =     3
   BAND-WIDTH                   =     6
   NO. OF SUPPORTED JOINTS      =     1
   ------------------------------------------------------------------------------
```

GLOBAL DISPLACEMENTS

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
1	1	.0000	.0000	.0000
2	1	.0000	-59.9999	-18.0000

ELEMENT - END DISPLACEMENTS

ELEMENT NUMBER	LOAD COMB.	JOINT NO.	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad
1	1	1	.0000	.0000	.0000
		2	.0000	-59.9999	-18.0000

ELEMENT - END FORCES

ELEMENT NUMBER	LOAD COMB.	JOINT NO.	AXIAL - X KN	SHEAR - Y KN	MOMENT - Z KN - m
1	1	1	.0000	.0321	.1603
		2	.0000	-.0321	.0000

SUPPORT REACTIONS

JOINT NO.	LOAD COMBINATION	FORCE - X KN	FORCE - Y KN	MOMENT - Z KN - m
1	1	.0000	.0321	.1603

APPENDIX - III

```
Analysis of two storeyed flats at sections A\D
    0
   16
    1      0.          0.              1
    4      0.          8.55
    5      3.6         0.              1
    8      3.6         8.55
    9      5.8         0.              1
   12      5.8         8.55
   13      10.         0.              1
   16      10.         8.55
    0
    0
   21
    1    1    2    1    7
   15
    3    5    6    1    7
   17
    5    9   10    1    7
   19
    7   13   14    1    7
   21
    2    2    6    2    2
    6
    9    3    7    2    2
   13
   16    4    8    3    2
   20
    0
    1    1    1    1    4
   13
    0
    3      28e6
.0525      .00023
.1025      .0017
.069       .0005
    2    2
Dead Load
    2    14.5  0.          0.              2
    6
    9    14.5  0.          0.              2
   13
   16     2.73 0.          0.              2
   20
    0
    0
    0
Live Load
    2     2.7  0.          0.              2
    6
    9     2.7  0.          0.              2
   13
   16     1.35 0.          0.              2
   20
    0
    0
    0
Dead Load Only
    1  1.0
    0
Dead+live Loads Only
    1  1.4
    2  1.6
```

```
     0
Global Joint Displacement
     1    16     1
     0
Element-End Local Displacement
     1    21     1
     0
Element End Forces
     1    21     1
     0
Support Reactions
     1    13     4
     0
Element End Forces Comparisor
     1    21     1
     0
```

STRUCTURAL ANALYSIS OF PLANE FRAMES

STRUCTURE NO. 05 Analysis of two storeys flat at sections A\D

CONTROL INFORMATION

NO. OF ELEMENTS	=	21
NO. OF JOINTS	=	16
NO. OF LOAD CASES	=	2
NO. OF LOAD COMBINATIONS	=	2

GENERAL DATA

ELASTICITY MODULUS = .2800E+08

JOINT DATA

JOINT NO.		X-FREEDOM	Y-FREEDOM	Z-FREEDOM	X-COORDINATE (METRES)	Y-COORDINATE (METRES
1	S	1	1	1	.0000	.000
2		0	0	0	.0000	2.850
3		0	0	0	.0000	5.700
4		0	0	0	.0000	8.550
5	S	1	1	1	3.6000	.000
6		0	0	0	3.6000	2.850
7		0	0	0	3.6000	5.700
8		0	0	0	3.6000	8.550
9	S	1	1	1	5.8000	.000
10		0	0	0	5.8000	2.850
11		0	0	0	5.8000	5.700
12		0	0	0	5.8000	8.550
13	S	1	1	1	10.0000	.000
14		0	0	0	10.0000	2.850
15		0	0	0	10.0000	5.700
16		0	0	0	10.0000	8.550

ELEMENT DATA

Section Property Data :

SECTION NUMBER	SECTION AREA (M4)	MOM. INERTIA (M4)
1	.0529	.0002
2	.1025	.0017
3	.0690	.0005

Element Connectivity Data :

ELEMENT NUMBER	LOWER JOINT	GREATER JOINT	SECTION NUMBER	ELEMENT LENGTH
1	1	2	1	2.8500
2	2	6	2	3.6000
3	5	6	1	2.8500
4	6	10	2	2.2000
5	9	10	1	2.8500
6	10	14	2	4.2000
7	13	14	1	2.8500
8	2	3	1	2.8500
9	3	7	2	3.6000
10	6	7	1	2.8500
11	7	11	2	2.2000
12	10	11	1	2.8500
13	11	15	2	4.2000
14	14	15	1	2.8500
15	3	4	1	2.8500
16	4	8	3	3.6000
17	7	8	1	2.8500
18	8	12	3	2.2000
19	11	12	1	2.8500
20	12	16	2	4.2000
21	15	16	1	2.8500

LOAD DATA

LOAD CASE 1 Dead Load

Element Uniform Load :

ELEMENT NUMBER	UNIFORM LOAD (KN/m)	DISTANCE FROM A-END START (m)	END (m)
2	14.5000	.00	3.60
4	14.5000	.00	2.20
6	14.5000	.00	4.20
9	14.5000	.00	3.60
11	14.5000	.00	2.20
13	14.5000	.00	4.20
16	2.7300	.00	3.60
18	2.7300	.00	2.20
20	2.7300	.00	4.20

Element Point Loads

ELEMENT NUMBER	PT. LOAD 1 (KN)	DIST. (M)	PT. LOAD 2 (KN)	DIST. (M)	PT. LOAD 3 (KN)	DIST (M)

Joint Loads

LOADED JOINT	HORIZONTAL LOAD-X (KN)	VERTICAL LOAD-Y (KN)	EXTERNA MOM.-Z (KN-m

LOAD CASE 2 Live Load

Element Uniform Load :

ELEMENT NUMBER	UNIFORM LOAD (KN/m)	DISTANCE FROM A-END START (m)	END (m)
2	2.7000	.00	3.60
4	2.7000	.00	2.20
6	2.7000	.00	4.20
9	2.7000	.00	3.60
11	2.7000	.00	2.20
13	2.7000	.00	4.20
16	1.3500	.00	3.60
18	1.3500	.00	2.20
20	1.3500	.00	4.20

Element Point Loads

ELEMENT NUMBER	PT. LOAD 1 (KN)	DIST. (M)	PT. LOAD 2 (KN)	DIST. (M)	PT. LOAD 3 (KN)	DIST. (M)

Joint Loads

LOADED JOINT	HORIZONTAL LOAD-X (KN)	VERTICAL LOAD-Y (KN)	EXTERNA MOM.-Z (KN-m

LOAD COMBINATION DATA

	LOAD COMBINATION NO./FACTORS	
LC	1	2
1	1.00	1.40
2	.00	1.60

LOAD COMBINATION 1 Dead Load Only

LOAD COMBINATION 2 Dead+live Loads Only

OUTPUT INFORMATION

Global Joint Displacement
1 16 1
Element-End Local Displacement
1 21 1
Element End Forces
1 21 1
Support Reactions
1 13 4
Element End Forces Comparison
1 21 1

SYSTEM DEGREES-OF-FREEDOM = 36
BAND-WIDTH = 15
NO. OF SUPPORTED JOINTS = 4

GLOBAL DISPLACEMENTS

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
1	1	.0000	.0000	.0000
	2	.0000	.0000	.0000
2	1	-.0284	-.1022	-.2736
	2	-.0481	-.1781	-.4657
3	1	-.0733	-.1582	-.2747
	2	-.1237	-.2775	-.4614
4	1	-.0942	-.1675	-.1073
	2	-.1646	-.2977	-.2572
5	1	.0000	.0000	.0000
	2	.0000	.0000	.0000
6	1	-.0267	-.1784	.1387
	2	-.0452	-.3105	.2351
7	1	-.0744	-.2755	.1241
	2	-.1251	-.4829	.2060
8	1	-.0977	-.2910	.0297
	2	-.1712	-.5166	.0932
9	1	.0000	.0000	.0000
	2	.0000	.0000	.0000
10	1	-.0261	-.2114	-.1995
	2	-.0441	-.3676	-.3391
11	1	-.0748	-.3249	-.1942
	2	-.1255	-.5691	-.3255
12	1	-.0991	-.3418	-.0736
	2	-.1738	-.6068	-.1819
13	1	.0000	.0000	.0000
	2	.0000	.0000	.0000
14	1	-.0234	-.1184	.4079
	2	-.0396	-.2063	.6939
15	1	-.0784	-.1834	.4076
	2	-.1276	-.3218	.6848
16	1	-.1048	-.1943	.1564
	2	-.1844	-.3453	.3767

ELEMENT - END DISPLACEMENTS

ELEMENT NUMBER	LOAD COMB.	JOINT NO.	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad
1	1	1	.0000	.0000	.0000
		2	-.1022	.0284	-.2736
	2	1	.0000	.0000	.0000
		2	-.1781	.0481	-.4657
2	1	2	-.0284	-.1022	-.2736
		6	-.0267	-.1784	.1387
	2	2	-.0481	-.1781	-.4657
		6	-.0452	-.3105	.2351
3	1	5	.0000	.0000	.0000
		6	-.1784	.0267	.1387
	2	5	.0000	.0000	.0000
		6	-.3105	.0452	.2351
4	1	6	-.0267	-.1784	.1387
		10	-.0261	-.2114	-.1995
	2	6	-.0452	-.3105	.2351
		10	-.0441	-.3676	-.3391
5	1	9	.0000	.0000	.0000
		10	-.2114	.0261	-.1995
	2	9	.0000	.0000	.0000
		10	-.3676	.0441	-.3391
6	1	10	-.0261	-.2114	-.1995
		14	-.0234	-.1184	.4079
	2	10	-.0441	-.3676	-.3391
		14	-.0396	-.2063	.6939
7	1	13	.0000	.0000	.0000
		14	-.1184	.0234	.4079
	2	13	.0000	.0000	.0000
		14	-.2063	.0396	.6939
8	1	2	-.1022	.0284	-.2736
		3	-.1582	.0733	-.2747
	2	2	-.1781	.0481	-.4657
		3	-.2775	.1237	-.4614
9	1	3	-.0733	-.1582	-.2747
		7	-.0744	-.2755	.1241
	2	3	-.1237	-.2775	-.4614
		7	-.1251	-.4829	.2060
10	1	6	-.1784	.0267	.1387
		7	-.2755	.0744	.1241
	2	6	-.3105	.0452	.2351
		7	-.4829	.1251	.2060
11	1	7	-.0744	-.2755	.1241
		11	-.0748	-.3249	-.1942
	2	7	-.1251	-.4829	.2060
		11	-.1255	-.5691	-.3255
12	1	10	-.2114	.0261	-.1995
		11	-.3249	.0748	-.1942
	2	10	-.3676	.0441	-.3391
		11	-.5691	.1255	-.3255
13	1	11	-.0748	-.3249	-.1942

		15	-.0764	-.1834	.4076
	2	11	-.1255	-.5691	-.3255
		15	-.1276	-.3218	.6848
14	1	14	-.1184	.0234	.4079
		15	-.1834	.0764	.4076
	2	14	-.2063	.0396	.6939
		15	-.3216	.1276	.6848
15	1	3	-.1582	.0733	-.2747
		4	-.1675	.0942	-.1073
	2	3	-.2775	.1237	-.4614
		4	-.2977	.1646	-.2572
16	1	4	-.0942	-.1675	-.1073
		8	-.0977	-.2910	.0297
	2	4	-.1646	-.2977	-.2572
		8	-.1712	-.5166	.0932
17	1	7	-.2755	.0744	.1241
		8	-.2910	.0977	.0297
	2	7	-.4829	.1251	.2060
		8	-.5166	.1712	.0932
18	1	8	-.0977	-.2910	.0297
		12	-.0991	-.3418	-.0736
	2	8	-.1712	-.5166	.0932
		12	-.1738	-.6068	-.1819
19	1	11	-.3249	.0748	-.1942
		12	-.3418	.0991	-.0736
	2	11	-.5691	.1255	-.3255
		12	-.6068	.1738	-.1819
20	1	12	-.0991	-.3418	-.0736
		16	-.1048	-.1943	.1564
	2	12	-.1738	-.6068	-.1819
		16	-.1844	-.3453	.3767
21	1	15	-.1834	.0764	.4076
		16	-.1943	.1048	.1564
	2	15	-.3218	.1276	.6848
		16	-.3453	.1844	.3767

ELEMENT - END FORCES

ELEMENT NUMBER	LOAD COMB.	JOINT NO.	AXIAL - X KN	SHEAR - Z KN	MOMENT - Z KN - m
1	1	1	53.1345	-1.3966	-1.3718
		2	-53.1345	1.3966	-2.6084
	2	1	92.5500	-2.3759	-2.3333
		2	-92.5500	2.3759	-4.4381
2	1	2	-1.3617	24.0602	6.5364
		6	1.3617	28.1398	-13.8794
	2	2	-2.2869	40.8542	11.0925
		6	2.2869	47.7778	-23.5550
3	1	5	92.7346	.5706	.4997
		6	-92.7346	-.5706	1.1266
	2	5	161.3776	.9674	.8473
		6	-161.3776	-.9674	1.9094
4	1	6	-.8411	14.1302	11.1658
		10	.8411	17.7698	-15.1688
	2	6	-1.4229	24.0064	18.9700
		10	1.4229	30.1576	-25.7363
5	1	9	109.8780	-1.0364	-1.0259
		10	-109.8780	1.0364	-1.9277
	2	9	191.0720	-1.7604	-1.7423
		10	-191.0720	1.7604	-3.2749
6	1	10	-1.8402	33.1064	20.0092
		14	1.8402	27.7936	-8.8522
	2	10	-3.0960	56.2026	33.9348
		14	3.0960	47.2014	-15.0322
7	1	13	61.5529	1.8623	1.7321
		14	-61.5529	-1.8623	3.5755
	2	13	107.2203	3.1691	2.9479
		14	-107.2203	-3.1691	6.0833
8	1	2	29.0743	-2.7583	-3.9280
		3	-29.0743	2.7583	-3.9330
	2	2	51.6959	-4.6629	-6.6544
		3	-51.6959	4.6629	-6.6347
9	1	3	.8713	24.2188	7.0003
		7	-.8713	27.9812	-13.7725
	2	3	1.1082	41.2027	12.1615
		7	-1.1082	47.4293	-23.5696
10	1	6	50.4646	1.0913	1.5880
		7	-50.4646	-1.0913	1.5221
	2	6	89.5934	1.8314	2.6754
		7	-89.5934	-1.8314	2.5443
11	1	7	.4340	14.4675	11.1051
		11	-.4340	17.4325	-14.3665
	2	7	.5465	24.6564	18.7615
		11	-.5465	29.5076	-24.0979
12	1	10	59.0018	-2.0355	-2.9127
		11	-59.0018	2.0355	-2.8885
	2	10	104.7119	-3.4335	-4.9236
		11	-104.7119	3.4335	-4.8620
13	1	11	1.1143	32.8137	19.4587

		15	-1.1143	28.0863	-9.5311
	2	11	1.4051	55.6127	32.9536
		15	-1.4051	47.7913	-16.5289
14	1	14	33.7593	3.7025	5.2767
		15	-33.7593	-3.7025	5.2753
	2	14	60.0190	6.2651	8.9483
		15	-60.0190	-6.2651	8.9071
15	1	3	4.8555	-1.8869	-3.0672
		4	-4.8555	1.8869	-2.3105
	2	3	10.4932	-3.5546	-5.5268
		4	-10.4932	3.5546	-4.6039
16	1	4	1.8869	4.8555	2.3105
		8	-1.8869	4.9725	-2.5210
	2	4	3.5546	10.4932	4.6039
		8	-3.5546	11.0420	-5.5918
17	1	7	8.0158	.6539	1.1453
		8	-8.0158	-.6539	.7184
	2	7	17.5076	1.2696	2.0640
		8	-17.5076	-1.2696	1.5544
18	1	8	1.2330	3.0433	1.8026
		12	-1.2330	2.9627	-1.7138
	2	8	2.2851	6.4656	4.0374
		12	-2.2851	6.6948	-4.2896
19	1	11	8.7556	-1.3552	-2.2037
		12	-8.7556	1.3552	-1.6586
	2	11	19.5916	-2.5749	-3.9938
		12	-19.5916	2.5749	-3.3447
20	1	12	2.5882	5.7930	3.3725
		16	-2.5882	5.6730	-3.1206
	2	12	4.8600	12.8968	7.6343
		16	-4.8600	12.2276	-6.2291
21	1	15	5.6730	2.5882	4.2558
		16	-5.6730	-2.5882	3.1206
	2	15	12.2276	4.8600	7.6218
		16	-12.2276	-4.8600	6.2291

SUPPORT REACTIONS

JOINT NO.	LOAD COMBINATION	FORCE - X KN	FORCE - Y KN	MOMENT - Z KN - m
1	1	1.3966	53.1345	-1.2718
	2	2.3759	92.5500	-2.3333
5	1	-.5706	92.7346	.4997
	2	-.9674	161.3776	.8473
9	1	1.0364	109.8780	-1.0259
	2	1.7604	191.0720	-1.7423
13	1	-1.8623	61.5529	1.7321
	2	-3.1691	107.2203	2.9479

COMPARISON OF ELEMENT-END FORCES

COMPARISON OF FORCES ALONG ELEMENTS 1 THRU 21 AT STEP 1

LOAD COMB	ELEM END	Max/Min AXIAL - X	On EL.	Max/Min SHEAR - Y	On EL.	Max/Min MOMENT - Z	On EL.
1	A-End	109.88	5	33.11	6	20.01	6
		-1.84	6	-2.76	8	-3.93	8
	B-End	1.84	6	28.14	2	5.28	14
		-109.88	5	-3.70	14	-15.17	4
2	A-End	191.07	5	56.20	6	33.93	6
		-3.10	6	-4.66	8	-6.65	8
	B-End	3.10	6	47.79	13	8.91	14
		-191.07	5	-6.27	14	-25.74	4

GLOBAL DISPLACEMENTS G31

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
1	1	.0000	.0000	.0000
2	1	2.3977	.0572	-.4494
3	1	7.1718	.0973	-.4737
4	1	11.8526	.1101	-.6877
5	1	.0000	.0000	.0000
6	1	2.3906	.2248	.1365
7	1	7.1736	.3410	-.0321
8	1	11.8714	.3666	-.1994
9	1	.0000	.0000	.0000
10	1	2.3802	-.4858	-1.8911
11	1	7.1761	-.7583	-2.0043
12	1	11.8995	-.8276	-2.0382
13	1	.0000	-19.7796	.0000
14	1	2.3626	-19.7759	-4.4848
15	1	7.1824	-19.6596	-4.2561
16	1	11.9456	-19.6289	-3.5476

COMPARISON OF ELEMENT-END FORCES G31

COMPARISON OF FORCES ALONG ELEMENTS 1 THRU 21 AT STEP 1

LOAD COMB	ELEM END	Max/Min AXIAL - X	On EL.	Max/Min SHEAR - Y	On EL.	Max/Min MOMENT - Z	On EL.
1	A-End	225.44	5	40.62	6	111.55	6
		-104.33	3	-58.41	4	-32.89	14
	B-End	104.33	3	58.41	4	60.40	13
		-225.44	5	-40.62	6	-103.42	4

GLOBAL DISPLACEMENTS G32

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
1	1	.0000	.0000	.0000
2	1	.9807	.2844	1.2010
3	1	3.1119	.4327	.4893
4	1	5.8232	.4656	-.0977
5	1	.0000	.0000	.0000
6	1	.9729	-1.6750	-5.4991
7	1	3.1173	-2.5826	-4.8854
8	1	5.8436	-2.8021	-4.3567
9	1	.0000	-19.2128	.0000
10	1	.9830	-17.9404	-3.7278
11	1	3.1149	-16.9109	-3.0966
12	1	5.8163	-16.6559	-2.6480
13	1	.0000	.0000	.0000
14	1	1.0182	-.4818	5.2504
15	1	3.1000	-.7520	4.3108
16	1	5.7244	-.8203	2.7306

COMPARISON OF ELEMENT-END FORCES G32

COMPARISON OF FORCES ALONG ELEMENTS 1 THRU 21 AT STEP 1

LOAD COMB	ELEM END	Max/Min AXIAL - X	On EL.	Max/Min SHEAR - Y	On EL.	Max/Min MOMENT - Z	On EL.
1	A-End	777.24	3	292.93	4	288.00	4
		-868.84	5	-98.17	6	-297.01	6
	B-End	868.84	5	98.17	6	356.44	4
		-777.24	3	-292.93	4	-192.77	3

Global Displacements G33

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
1	1	.0000	.0000	.0000
2	1	5.5372	1.5337	6.3987
3	1	17.5215	2.3345	2.5740
4	1	32.6104	2.5127	-.6025
5	1	.0000	.0000	.0000
6	1	5.4948	-8.9696	-29.5161
7	1	17.5503	-13.8305	-26.2393
8	1	32.7218	-15.0068	-23.4185
9	1	.0000	-106.3993	.0000
10	1	5.5478	-96.3992	-20.2327
11	1	17.5377	-90.9014	-16.8559
12	1	32.5785	-89.5396	-14.4504
13	1	.0000	-2.2564	.0000
14	1	5.7349	-4.8206	27.6895
15	1	17.4584	-6.2586	22.6696
16	1	32.0903	-6.6221	14.2645

COMPARISON OF ELEMENT-END FORCES G33

COMPARISON OF FORCES ALONG ELEMENTS 1 THRU 21 AT STEP 1

SUPPORT REACTIONS

SUPPORT REACTIONS

LOAD COMB	ELEM END	Max/Min AXIAL - X	On EL.	Max/Min SHEAR - Y	On EL.	Max/Min MOMENT - Z	On EL.
1	A-End	4162.19	3	1566.50	4	1543.81	4
		-4640.40	5	-522.61	6	-1582.40	6
	B-End	4640.40	5	522.61	6	1902.49	4
		-4162.19	3	-1566.50	4	-1036.07	2

Global Displacements: G35

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 ROTATION 1.0E-3 rad.
1	1	.0000	-19.9912	.0000
2	1	.0000	.0000	.0000
3	1	.0000	.0000	.0000
4	1	-1.8224	-19.9028	-3.1787
5	1	-1.8371	-.0791	1.2436
6	1	-1.8468	.1008	.0308
7	1	-5.8462	-19.8538	-3.0758
8	1	-5.8402	-.1263	1.5096
9	1	-5.8386	.1646	.1209
10	1	-10.2349	-19.8411	2.6082
11	1	-10.1977	-.1388	1.5344
12	1	-10.1728	.1819	.5082

COMPARISON OF ELEMENT-END FORCES G35

COMPARISON OF FORCES ALONG ELEMENTS 1 THRU 15 AT STEP 1

LOAD COMB	ELEM END	Max/Min AXIAL - X	On EL.	Max/Min SHEAR - Y	On EL.	Max/Min MOMENT - Z	On EL.
1	A-End	87.80	3	21.57	9	59.34	9
		-46.79	5	-18.29	2	-38.88	2
	B-End	46.79	5	18.29	2	31.24	9
		-87.80	3	-21.57	9	-67.23	3

GLOBAL DISPLACEMENTS G36

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
1	1	.0000	.0000	.0000
2	1	.0000	-19.9806	.0000
3	1	.0000	.0000	.0000
4	1	-1.2706	-.1891	-2.9471
5	1	-1.2358	-19.7863	.8698
6	1	-1.2126	-.2754	4.6534
7	1	-3.9138	-.3018	-2.6588
8	1	-3.9264	-19.6732	1.0422
9	1	-3.9356	-.4335	4.3865
10	1	-6.7839	-.3317	-1.4775
11	1	-6.8717	-19.6431	1.0498
12	1	-6.9317	-.4753	3.5181

COMPARISON OF ELEMENT-END FORCES G36

COMPARISON OF FORCES ALONG ELEMENTS 1 THRU 15 AT STEP 1

LOAD COMB	ELEM END	Max/Min AXIAL - X	On EL.	Max/Min SHEAR - Y	On EL.	Max/Min MOMENT - Z	On EL.
1	A-End	127.81	5	38.38	7	84.18	
		-215.57	3	-54.47	4	-152.66	4
	B-End	215.57	3	54.47	4	138.42	7
		-127.81	5	-38.38	7	-79.49	5

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GLOBAL DISPLACEMENTS G37 177

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
1	1	.0000	-22648.5300	.0000
2	1	.0000	-13.9505	.0000
3	1	.0000	.0000	.0000
4	1	-2065.5070	-22548.5500	3599.1300
5	1	-2082.1430	-103.4554	1409.4720
6	1	-2093.0460	114.0327	38.1661
7	1	-6628.1580	-22493.1600	3432.8310
8	1	-6619.1940	-156.7940	1710.9290
9	1	-6617.3300	186.1965	140.0092
10	1	-11600.0300	-22478.7500	2953.8890
11	1	-11557.9300	-171.0118	1739.1200
12	1	-11529.7100	205.7832	578.2402

COMPARISON OF ELEMENT-END FORCES G37

COMPARISON OF FORCES ALONG ELEMENTS 1 THRU 15 AT STEP 1

LOAD COMB	ELEM END	Max/Min AXIAL - X	On EL.	Max/Min SHEAR - Y	On EL.	Max/Min MOMENT - Z	On EL.
1	A-End	99319.06	3	24395.73	9	67127.25	9
		-52915.19	5	-20702.35	2	-43991.91	2
	B-End	52915.19	5	20702.35	2	35334.82	9
		-99319.06	3	-24395.73	9	-76081.72	2

GLOBAL DISPLACEMENTS G41

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
4	1	.0000	.0000	.0000
5	1	2.3871	.1586	.2121
6	1	6.9973	.1749	-.0334
7	1	.0000	.0000	.0000
8	1	2.3787	-.3061	-1.8231
9	1	7.0267	-.3875	-1.9216
10	1	.0000	-19.9876	.0000
11	1	2.3648	-19.8641	-4.6139
12	1	7.0778	-19.8302	-3.6059

COMPARISON OF ELEMENT-END FORCES G41

COMPARISON OF FORCES ALONG ELEMENTS 4 THRU 14 AT STEP 1

LOAD COMB	ELEM END	Max/Min AXIAL - X	On EL.	Max/Min SHEAR - Y	On EL.	Max/Min MOMENT - Z	On EL.
1	A-End	142.05	5	41.58	6	110.56	4
		-57.32	7	-62.64	4	-31.89	14
	B-End	57.32	7	62.64	4	59.08	6
		-142.05	5	-41.58	6	-108.22	4

COMPARISON OF ELEMENT-END FORCES G42

COMPARISON OF FORCES ALONG ELEMENTS 4 THRU 14 AT STEP 1

LOAD COMB	ELEM END	Max/Min AXIAL - X	On EL.	Max/Min SHEAR - Y	On EL.	Max/Min MOMENT - Z	On EL.
1	A-End	141.27	7	315.65	4	313.57	4
		-565.84	5	-103.93	6	-317.08	6
	B-End	565.84	5	103.93	6	380.87	4
		-141.27	7	-315.65	4	-119.44	6

GLOBAL DISPLACEMENTS G42

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
4	1	.0000	.0000	.0000
5	1	.9846	-1.1156	-5.8493
6	1	3.7970	-1.3973	-5.0320
7	1	.0000	-19.8781	.0000
8	1	.9925	-18.6587	-4.1077
9	1	3.7692	-18.3435	-3.3446
10	1	.0000	.0000	.0000
11	1	1.0221	-.3044	5.6581
12	1	3.6594	-.3849	3.1154

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GLOBAL DISPLACEMENTS G43

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
4	1	.0000	.0000	.0000
5	1	83.7105	-51.6824	-481.1121
6	1	320.3304	-114.7669	-414.1280
7	1	.0000	-1635.7930	.0000
8	1	84.3481	-1535.7920	-340.0795
9	1	318.0808	-1509.9470	-277.3957
10	1	.0000	-22.4913	.0000
11	1	86.7667	-47.4043	460.4224
12	1	309.0967	-53.9869	252.2807

COMPARISON OF ELEMENT-END FORCES G43

COMPARISON OF FORCES ALONG ELEMENTS 4 THRU 14 AT STEP 1

LOAD COMB	ELEM END	Max/Min AXIAL - X	On EL.	Max/Min SHEAR - Y	On EL.	Max/Min MOMENT - Z	On EL.
1	A-End	11560.53	7	25905.14	4	25771.17	4
		-46403.97	5	-8503.98	6	-25963.87	6
	B-End	46403.97	5	8505.98	6	31220.15	4
		-11560.53	7	-25905.14	4	-9762.23	6

GLOBAL DISPLACEMENTS G45

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
1	1	.0000	-19.9947	.0000
2	1	.0000	.0000	.0000
3	1	.0000	.0000	.0000
4	1	-1.8015	-19.9414	3.2374
5	1	-1.8112	-.0442	1.2222
6	1	-1.8182	.0526	-.0176
7	1	-5.7210	-19.9274	2.4966
8	1	-5.6784	-.0570	1.4421
9	1	-5.6547	.0690	.4165

COMPARISON OF ELEMENT-END FORCES G45

COMPARISON OF FORCES ALONG ELEMENTS 1 THRU 10 AT STEP 1

LOAD COMB	ELEM END	Max/Min AXIAL - X	On EL.	Max/Min SHEAR - Y	On EL.	Max/Min MOMENT - Z	On EL.
1	A-End	49.09	3	16.75	4	47.71	4
		-24.70	1	-18.20	2	-38.42	3
	B-End	24.70	1	18.20	2	30.19	3
		-49.09	3	-16.75	4	-67.56	2

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GLOBAL DISPLACEMENTS G46

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
1	1	.0000	.0000	.0000
2	1	.0000	-19.9889	.0000
3	1	.0000	.0000	.0000
4	1	-1.2766	-.1058	-3.0894
5	1	-1.2534	-19.8775	.8855
6	1	-1.2365	-.1606	4.7697
7	1	-3.8676	-.1362	-1.4896
8	1	-3.9589	-19.8463	1.0187
9	1	-4.0243	-.2048	3.5064

COMPARISON OF ELEMENT-END FORCES G46

LOAD COMB	ELEM END	Max/Min AXIAL - X	On EL.	Max/Min SHEAR - Y	On EL.	Max/Min MOMENT - Z	On EL.
1	A-End	74.50	5	34.98	2	72.30	2
		-123.58	3	-53.97	4	-152.65	4
	B-End	123.58	3	53.97	4	130.56	2
		-74.50	5	-34.98	2	-74.04	4

GLOBAL DISPLACEMENTS G47

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
1	1	.0000	-37591.8800	.0000
2	1	.0000	-13.3104	.0000
3	1	.0000	.0000	.0000
4	1	-3387.8140	-37491.8700	6084.5020
5	1	-3406.0590	-96.4146	-2298.3980
6	1	-3419.1350	98.7251	-29.9462
7	1	-10758.6300	-37465.5800	4692.8170
8	1	-10678.5900	-120.3544	2711.9190
9	1	-10634.0400	129.6774	785.3105

COMPARISON OF ELEMENT-END FORCES G47

COMPARISON OF FORCES ALONG ELEMENTS 1 THRU 10 AT STEP 1

LOAD COMB	ELEM END	Max/Min AXIAL - X	On EL.	Max/Min SHEAR - Y	On EL.	Max/Min MOMENT - Z	On EL
1	A-End	92216.53	3	31448.97	4	89603.47	
		-46403.84	1	-34202.78	2	-72248.52	
	B-End	46403.84	1	34202.78	2	56784.38	
		-92216.53	3	-31448.97	4	-126931.10	

GLOBAL DISPLACEMENTS G51

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
1	1	.0000	.0000	.0000
2	1	2.4893	.0001	-.3070
3	1	.0000	.0000	.0000
4	1	2.4979	.1219	.3727
5	1	.0000	.0000	.0000
6	1	2.5109	-.1932	-1.7334
6	1	2.5109	-.1932	-1.7334
7	1	.0000	-19.9927	.0000
8	1	2.5359	-19.9216	-5.3738

COMPARISON OF ELEMENT-END FORCES G51

COMPARISON OF FORCES ALONG ELEMENTS 1 THRU 7 AT STEP 1

LOAD COMB	ELEM END	Max/Min AXIAL - X	On EL.	Max/Min SHEAR - Y	On EL.	Max/Min MOMENT - Z	On EL.
1	A-End	89.66	5	33.06	6	106.27	6
		-56.56	3	-56.60	4	-21.57	4
	B-End	56.56	3	56.60	4	32.60	6
		-89.66	5	-33.06	6	-102.95	4

COMPARISON OF ELEMENT-END FORCES G52

COMPARISON OF FORCES ALONG ELEMENTS 1 THRU 7 AT STEP 1

LOAD COMB	ELEM END	Max/Min AXIAL - X	On EL.	Max/Min SHEAR - Y	On EL.	Max/Min MOMENT - Z	On EL.
1	A-End	356.72	3	286.53	4	281.65	4
		-375.86	5	-89.33	6	-312.33	6
	B-End	375.86	5	89.33	6	348.72	4
		-356.72	3	-286.53	4	-231.31	3

GLOBAL DISPLACEMENTS G52

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
1	1	.0000	.0000	.0000
2	1	.4530	.1512	2.4072
3	1	.0000	.0000	.0000
4	1	.4692	-.7687	-6.4852
5	1	.0000	-19.9190	.0000
6	1	.4567	-19.1090	-4.7493
7	1	.0000	.0000	.0000
8	1	.4020	-.1925	7.5775

GLOBAL DISPLACEMENTS G53

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
1	1	.0000	.0000	.0000
2	1	58.8302	18.7131	297.4852
3	1	.0000	.0000	.0000
4	1	60.8517	-94.9753	-801.9730
5	1	.0000	-2434.5120	.0000
6	1	59.3183	-2364.5100	-589.5550
7	1	.0000	-22.3739	.0000
8	1	52.5765	-46.1127	931.5306

GLOBAL DISPLACEMENTS G55

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
1	1	.0000	-19.9974	.0000
2	1	-2.3858	-19.9715	3.6891
3	1	.0000	.0000	.0000
4	1	-2.3664	-.0144	1.6045
5	1	.0000	.0000	.0000
6	1	-2.3498	.0035	.4158

COMPARISON OF ELEMENT-END FORCES G55

COMPARISON OF FORCES ALONG ELEMENTS 1 THRU 5 AT STEP 1

LOAD COMB	ELEM END	Max/Min	On	Max/Min SHEAR - Y	On EL.	Max/Min MOMENT - Z	On EL.
1	A-End	15.97	2	8.56	1	9.88	5
		12.04	1	-12.04	4	-60.37	2
	B-End	12.04	1	12.04	4	40.31	2
		-15.97	2	-8.56	1	-50.19	4

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Global Displacements G56

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
1	1	.0000	.0000	.0000
2	1	1.3111	-.0344	-3.8193
3	1	.0000	-19.9933	.0000
4	1	1.2832	-19.9652	-.9472
5	1	.0000	.0000	.0000
6	1	1.2353	-.0327	2.6819

COMPARISON OF ELEMENT-END FORCES G56

COMPARISON OF FORCES ALONG ELEMENTS 1 THRU 5 AT STEP 1

LOAD COMB	ELEM END	Max/Min AXIAL - X	On EL.	Max/Min SHEAR - Y	On EL.	Max/Min MOMENT - Z	On EL.
1	A-End	15.97	1	15.97	4	25.25	4
		-31.14	2	-15.17	5	-36.83	5
	B-End	31.14	2	15.17	5	67.35	4
		-15.97	1	-15.97	4	-30.52	3

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GLOBAL DISPLACEMENTS G57

JOINT NO.	LOAD COMBINATION	X - MOVEMENT (mm)	Y - MOVEMENT (mm)	Z - ROTATION 1.0E-3 rad.
1	1	.0000	-77095.1800	.0000
2	1	-9197.2400	-76995.1700	14220.3100
3	1	.0000	-10.5465	.0000
4	1	-9122.5790	-66.0121	6185.2110
5	1	.0000	.0000	.0000
6	1	-9058.4720	32.6328	1604.3220

COMPARISON OF ELEMENT-END FORCES G57

COMPARISON OF FORCES ALONG ELEMENTS 1 THRU 5 AT STEP 1

LOAD COMB	ELEM END	Max/Min AXIAL - X	On EL.	Max/Min SHEAR - Y	On EL.	Max/Min MOMENT - Z	On EL.
1	A-End	61547.37	2	32986.25	1	38071.26	5
		-46405.98	1	-46404.63	4	-191859.90	2
	B-End	46405.98	1	46404.63	4	155380.10	2
		-61547.37	2	-32986.25	1	-193451.30	4

```
      1 C
      2 C
      3       PROGRAM FRAME1
      4 C
      5 C  PLANE FRAME PROGRAM BY IMAM  M. R. I.
      6 C  ADOPTED AND MODIFIED FROM AZIZ(1987)
      7 C                                                          COM(10)*50
      8       CHARACTER DR1*2,FNINN*10,FNOUT*10,SN*2,TITLE*80,CAS*50,
      9      1,AS*1,FF*1,DR2*2
     10 C
     11       COMMON /JD/C(200,2),JR(200,3),NSJ(60)
     12       COMMON /ED/MC(360,2),MS(360),S(50,2),XL(360),M(360,6)
     13       COMMON /LD/FE(3600,6),Q(5500),F(10,10),CL(3),D(6)
     14       COMMON /TR/XK(6,6)
     15       DIMENSION ISS(50),SSS(50,3)
     16 C
     17       WRITE(*,10)'  Enter Data Disk Drive [A:,B:,C:] '
     18    10 FORMAT(5X,A$)
     19       READ(*,15)DR1
     20    15 FORMAT(3A)
     21       WRITE(*,10)'  Enter Structure Number [2 Digits] '
     22       READ(*,15)SN
     23       WRITE(*,10)'  Enter Analysis Disk Drive [A:,B:,C:] '
     24       READ(*,15)DR2
     25       FNINN(1:2)=DR1
     26       FNOUT(1:2)=DR1
     27       FNINN(3:2+6)='DATA.G'
     28       FNOUT(3:2+6)='DOUT.G'
     29       FNINN(9:10)=SN
     30       FNOUT(9:10)=SN
     31       OPEN(1,FILE=FNINN)
     32       OPEN(2,FILE=FNOUT,STATUS='NEW')
     33       OPEN(3,FILE='A:GRIL.DAT',ACCESS='DIRECT',FORM='FORMATTED',
     34      1        STATUS='NEW',RECL=6)
     35       WRITE(3,15)DR2,SN,DR1
     36       CLOSE(3)
     37       FF=CHAR(12)
     38 C
     39 C READ TITLE OF STRUCTURE
     40 C
     41       READ(1,'(A)')TITLE
     42 C
     43 C  READ JOINT CO-ORDINATES
     44 C
     45       JMFLAG=0
     46       READ(1,20)JCO
     47       IF(JCO)30,30,40
     48    30 TH=0
     49       READ(1,20)NJ
     50    20 FORMAT(I5,5X,2E10.0,I5)
     51    70 READ(1,20)J,(C(J,I),I=1,2),IS
     52       IF(J)45,45,50
     53    50 IF(IS)70,70,80
     54    80 READ(1,20)N,(C(N,I),I=1,2)
     55       DF=(N-J)/IS
     56       RX=(C(N,1)-C(J,1))/DF
```

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D Line# 1      7                                  Microsoft FORTRAN77 V3.30 March 1
      57       RY=(C(N,2)-C(J,2))/DF
      58       DO 60 I=J+IS,N-IS,IS
1     59       C(I,1)=C(I-IS,1)+RX
1     60    60 C(I,2)=C(I-IS,2)+RY
      61       GOTO 70
      62    40 CALL SUBJC(TH,NL,NT,NJ,JMFLAG)
      63 C
      64 C  READ ELEMENT CONNECTIVITY & SECTION NUMBERS
      65 C
      66    45 READ(1,20)MCO
      67       IF(MCO)90,90,100
      68    90 READ(1,110)NE
      69   140 READ(1,110)J,(MC(J,I),I=1,2),MS(J),IS
      70   110 FORMAT(5I5)
      71       IF(J)120,120,130
      72   130 IF(IS)140,140,150
      73   150 READ(1,110)N
      74       ID=IABS(IABS(MC(J,1))-IABS(MC(J,2)))
      75       DO 160 I=J+IS,N,IS
1     76       MC(I,1)=MC(I-IS,2)
1     77       MC(I,2)=MC(I-IS,2)+ID
1     78   160 MS(I)=MS(J)
      79       GOTO 140
      80   100   CALL SUBMC(NL,NT,NE,JMFLAG)
      81 C
      82 C  READ JOINT RELEASES
      83 C
      84   120 READ(1,110)J,(JR(J,I),I=1,3),IS
      85       IF(J)170,170,180
      86   180 IF(IS)120,120,190
      87   190 READ(1,110)N
      88       DO 200 I=J+IS,N,IS
1     89       DO 200 L=1,3
2     90   200 JR(I,L)=JR(I-IS,L)
      91       GOTO 120
      92 C
      93 C READ SPRING DATA
      94 C
      95   170 READ(1,20)NSS
      96       DO 1310 I=1,NSS
1     97  1310 READ(1,650)ISS(I),(SSS(I,J),J=1,3)
      98 C
      99 C
     100 C COMPUTE NO. OF SUPPORTED JOINTS
     101 C
     102       NSU=0
     103       DO 176 I=1,NJ
1    104       DO 175 L=1,3
2    105       IF(JR(I,L)-1)175,171,175
2    106   171 NSU=NSU+1
2    107       NSJ(NSU)=I
2    108       GOTO 176
2    109   175 CONTINUE
1    110       IF(NSS-1)176,176,178
1    111   178 DO 177 J=1,NSS
2    112       IF(I-ISS(J))177,179,177
```

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D Line# 1      7                                  Microsoft FORTRAN77 V3.30 March 1
2    113    179 NSU=NSU+1
2    114        NSJ(NSU)=I
2    115    177 CONTINUE
1    116    176 CONTINUE
     117 C
     118 C  READ MATERIAL PROPERTIES
     119 C
     120        READ(1,20)NS,E,G
     121        READ(1,310)((S(I,J),J=1,2),I=1,NS)
     122    310 FORMAT(2E10.0)
     123 C
     124 C  READ LOAD INFORMATION
     125        READ(1,110)LC,NLC
     126 C
     127 C  WRITE INPUT DATA TO FILE 2
     128 C
     129        WRITE(2,'(A///3X,A)')FF,'STRUCTURAL ANALYSIS OF PLANE FRAMES'
     130        CALL SPAC1
     131        WRITE(2,385)SN,TITLE
     132    385 FORMAT(///3X'STRUCTURE NO. 'A2,3X,A)
     133        CALL SPAC1
     134        WRITE(2,390)NE,NJ,NSS,LC,NLC,E
     135    390 FORMAT(///3X'CONTROL INFORMATION'//10X
     136       1'NO. OF ELEMENTS                = 'I5/10X
     137       2'NO. OF JOINTS                  = 'I5/10X
     138       7'NO. OF SPRINGS                 = 'I5/10X
     139       3'NO. OF LOAD CASES              = 'I5/10X
     140       4'NO. OF LOAD COMBINATIONS       = 'I5//3X
     141       5'GENERAL DATA'//10X
     142       6'ELASTICITY MODULUS       = 'E10.4/10X)
     143        CALL SPAC1
     144
     145        WRITE(2,400)
     146    400 FORMAT(//3X'JOINT DATA'//3X
     147       1'JOINT'2X'X-FREEDOM'3X'Y-FREEDOM'3X'Z-FREEDOM'3X'X-COORDINATE'
     148       23X'Y-COORDINATE'/3X,2X'NO.'42X'(METRES)'7X'(METRES)'/)
     149        LP=36
     150        DO 410 I=1,NJ
1    151        AS=' '
1    152        DO 415 J=1,NSU
2    153        IF(I-NSJ(J))415,416,415
2    154    416 AS='S'
2    155        GOTO 417
2    156    415 CONTINUE
1    157    417 WRITE(2,420)I,AS,(JR(I,J),J=1,3),(C(I,J),J=1,2)
1    158    420 FORMAT(3X,I5,1X,A1,8X,I1,2(11X,I1),2(3X,F12.4))
1    159        LP=LP+1
1    160    410 IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
     161        CALL SPAC1
     162        LP=LP+2
     163        IF(MOD(LP,56).EQ.0)WRITE(2,999)FF
     164    999 FORMAT(A)
     165 C
     166 C FORM EQUATION NUMBERS IN JOINT RELEASES
     167 C
     168        L=1
```

```
D Line# 1      7                                  Microsoft FORTRAN77 V3.30 March 1
     169           DO 210 I=1,NJ
1    170           DO 210 J=1,3
2    171           IF(JR(I,J)-1)220,230,240
2    172     220   JR(I,J)=L
2    173           L=L+1
2    174           GOTO 210
2    175     230   JR(I,J)=0
2    176           GOTO 210
2    177     240   K=JR(I,J)
2    178           JR(I,J)=JR(K,J)
2    179     210   CONTINUE
     180 C
     181 C  FORM MEMBER CODE MATRIX
     182 C
     183           DO 250 I=1,NE
1    184           DO 250 L=1,2
2    185           DO 250 K=L*L,3*L
3    186           J=IABS(MC(I,L))
3    187           N=K-3*(L-1)
3    188     250   M(I,K)=JR(J,N)
     189 C
     190 C  REMOVE D.O.F. CORRESSPONDING TO PINNED ENDS
     191 C
     192           DO 260 N=1,NE
1    193           DO 260 J=1,2
2    194           IF(MC(N,J))270,280,260
2    195     280   WRITE(*,'(5X,A,I5,A)')'Element ',N,' Connects to Joint ZERO'
2    196     270   L=M(N,(J-1)*3+3)
2    197           M(N,(J-1)*3+3)=0
2    198           DO 290 I=1,NE
3    199           DO 290 K=1,6
4    200           IF(M(I,K)-L)290,290,300
4    201     300   M(I,K)=M(I,K)-1
4    202     290   CONTINUE
2    203     260   CONTINUE
     204 C
     205 C  RE-ADJUST JOINT RELEASES
     206 C
     207           DO 320 N=1,NJ
1    208           DO 330 NN=1,2
2    209           DO 330 L=1,NE
3    210           DO 330 J=1,2
4    211           IF(NN-1)340,340,350
4    212     340   IF(MC(L,J)-N)330,360,330
4    213     350   IF(IABS(MC(I,J)-N))330,360,330
4    214     360   JJ=L
4    215           KK=J
4    216           GOTO 370
4    217     330   CONTINUE
1    218     370   DO 380 J=1,3
2    219           K=(KK-1)*3+J
2    220     380   JR(N,J)=M(JJ,K)
1    221     320   CONTINUE
     222 C
     223           FNOUT(3:2+6)='INFO.G'
     224           OPEN(3,FILE=FNOUT,STATUS='NEW')
```

```
D Line# 1      7                                  Microsoft FORTRAN77 V3.30 March 19
     225       WRITE(3,'((3I5))')((JR(I,J),J=1,3),I=1,NJ)
     226       DO 321 N=1,8
1    227       IF(MOD(LP+N,56))321,322,321
1    228    322 WRITE(2,999)FF
1    229       LP=LP+N
1    230       GOTO 323
1    231    321 CONTINUE
     232    323 WRITE(2,430)
     233    430 FORMAT(//3X'ELEMENT DATA'//3X'Section Property Data :'//3X
     234       14X'SECTION'12X'SECTION AREA'12X'MOM. INERTIA'/3X
     235       25X'NUMBER'11X'          (M2)'11X'          (M4)'/)
     236       LP=LP+8
     237       DO 444 I=1,NS
1    238       WRITE(2,440)I,(S(I,J),J=1,2)
1    239       LP=LP+1
1    240    444 IF(MOD(LP,56).EQ.0)WRITE(2,999)FF
     241    440 FORMAT((9X,I5,2(11X,F13.9)))
     242       CALL SPAC1
     243       LP=LP+2
     244       IF(MOD(LP,56).EQ.0)WRITE(2,999)FF
     245 C
     246 C COMPUTE ELEMENT LENGTHS & TRANSFORM MATERIAL PROPERTIES
     247 C
     248       DO 500 I=1,NE
1    249       J=IABS(MC(I,1))
1    250       N=IABS(MC(I,2))
1    251       XL(I)=SQRT((C(N,1)-C(J,1))**2+(C(N,2)-C(J,2))**2)
1    252       IF(XL(I))490,490,500
1    253    490 WRITE(*,'(5X,A,I5,A,E10.4)')'Error Length of Element',I,'=',XL(I)
1    254    500 CONTINUE
     255       TH=TH*ATAN(1.0)/45.0
     256       DO 510 I=1,NS
1    257       DO 510 J=1,2
2    258       S(I,J)=S(I,J)/COS(TH)
2    259    510 CONTINUE
     260 C
     261       DO 511 N=1,6
1    262       IF(MOD(LP+N,56))511,522,511
1    263    522 WRITE(2,999)FF
1    264       LP=LP+N
1    265       GOTO 523
1    266    511 CONTINUE
     267    523 WRITE(2,450)
     268    450 FORMAT(//3X'Element Connectivity Data :'//3X
     269       1'ELEMENT'6X'LOWER'6X'GREATER'6X'SECTION'10X'ELEMENT'/3X
     270       21X'NUMBER'6X'JOINT'8X'JOINT'7X'NUMBER'11X'LENGTH'/)
     271       LP=LP+6
     272       DO 460 I=1,NE
1    273       WRITE(2,470)I,(MC(I,J),J=1,2),MS(I),XL(I)
1    274    470 FORMAT((5X,I5,6X,I5,2(8X,I5),5X,F12.4))
1    275       LP=LP+1
1    276    460 IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
     277       CALL SPAC1
     278 C
     279 C COMPUTE SYSTEM DEGREE-OF-FREEDOM & HALF BAND WIDTH
     280 C
```

```
D Line# 1      7                                  Microsoft FORTRAN77 V3.30 March 1
     281       ND=M(1,1)
     282       NB=0
     283       DO 520 I=1,NE
1    284       KB=IABS(IABS(MC(I,1))-IABS(MC(I,2)))
1    285       IF(KB.GT.NB)NB=KB
1    286       DO 520 J=1,6
2    287       IF(ND-M(I,J))530,520,520
2    288   530 ND=M(I,J)
2    289   520 CONTINUE
     290       NB=(NB+1)*3
     291 C
     292 C WRITE SPRING DATA
     293 C
     294       IF(NSS)1230,1230,1240
     295  1240 WRITE(2,'(A//3X,A)')FF,'SPRING STIFFNESSES'
     296       WRITE(2,1250)
     297  1250 FORMAT(//4X,'LOADED'8X'X - DIRECTION'8X'Y - DIRECTION'8X
     298      1'Z - DIRECTION'/5X'JOINT'13X'KN/m'17X'KN/m'15X'KN-M/rad.'/)
     299       DO 1260 J=1,NSS
1    300  1260 WRITE(2,840)ISS(J),(SSS(J,L),L=1,3)
     301 C
     302 C  READ/WRITE LOADINGS, AND COMPUTE FIXED-END FORCES
     303 C
     304  1230 WRITE(2,'(A//3X,A)')FF,'LOAD DATA'
     305       LP=0
     306       DO 525 K=1,LC
1    307       READ(1,'(A)')CAS
1    308       DO 541 N=1,9
2    309       IF(MOD(LP+N,56))541,542,541
2    310   542 WRITE(2,999)FF
2    311       LP=LP+N
2    312       GOTO 543
2    313   541 CONTINUE
1    314   543 WRITE(2,535)K,CAS
1    315   535 FORMAT(/3X'LOAD CASE'I5,5X,A/)
1    316       CALL SPAC1
1    317 C UNIFORM LOAD
1    318       WRITE(2,540)
1    319   540 FORMAT(3X'Element Uniform Load :'/3X
1    320      12X'ELEMENT'10X'UNIFORM'13X'DISTANCE FROM A-END'/3X
1    321      23X'NUMBER'6X'LOAD (KN/m)'9X'START (m)'10X'END (m)'/)
1    322       LP=LP+9
1    323       IF(MOD(LP,56).EQ.0)WRITE(2,999)FF
1    324   630 READ(1,550)N,W,A1,A3,IS
1    325   550 FORMAT(I5,3E10.0,I5)
1    326       IF(N)560,560,570
1    327   570 IF(IS)580,580,590
1    328   580 NN=N
1    329       IS=1
1    330       GOTO 600
1    331   590 READ(1,550)NN
1    332   600 DO 610 J=N,NN,IS
2    333       IF(A3)601,601,602
2    334   601 A2=XL(J)
2    335       GOTO 603
2    336   602 A2=A3
```

```
D Line# 1      7                                  Microsoft FORTRAN77 V3.30 March 19
2    337    603 WRITE(2,620)J,W,A1,A2
2    338    620 FORMAT(7X,I5,5X,F12.4,6X,F12.2,5X,F12.2)
2    339        LP=LP+1
2    340        IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
2    341        I=(K-1)*NE+J
2    342        FE(I,2)=FE(I,2)+W*(A2-A1)*((A1+A2+XL(J))*(XL(J)-(A1+A2)/2.0)**2
2    343       1+(A1+A2-XL(J))/4.0*(A2-A1)**2)/XL(J)**3
2    344        FE(I,3)=FE(I,3)+W*XL(J)*((XL(J)-A1)**3*(XL(J)+3*A1)-(XL(J)-A2)
2    345       1**3*(XL(J)+3*A2))/(12*XL(J)**2*(A2-A1))
2    346        FE(I,5)=FE(I,5)+W*(A2-A1)*((3*XL(J)-A1-A2)*(A1+A2)**2/4.0
2    347       1-(A1+A2-XL(J))/4.0*(A2-A1)**2)/XL(J)**3
2    348        FE(I,6)=FE(I,6)-W*XL(J)*(A2**3*(4*XL(J)-3*A2)-A1**3*(4*XL(J)-
2    349       1-3*A1))/(12*XL(J)**2*(A2-A1))
2    350    610 CONTINUE
1    351        GOTO 630
1    352    560 CALL SPAC1
1    353        LP=LP+2
1    354        DO 641 N=1,5
2    355        IF(MOD(LP+N,56))641,642,641
2    356    642 WRITE(2,999)FF
2    357        LP=LP+N
2    358        GOTO 643
2    359    641 CONTINUE
1    360 C  ELEMENT POINT LOADS
1    361    643 WRITE(2,640)
1    362    640 FORMAT(/3X'Element Point Loads'//3X,
1    363       1'ELEMENT'4X'PT. LOAD'4X'DIST.'4X'PT. LOAD'4X'DIST.'4X'PT. LOAD'
1    364       24X'DIST.'/3X,1X'NUMBER'4X'1 (KN) '5X'(M)'6X'2 (KN) '5X'(M)'6X
1    365       3'3 (KN) '5X'(M)'/)
1    366        LP=LP+5
1    367        IF(MOD(LP,56).EQ.0)WRITE(2,999)FF
1    368    730 READ(1,650)N,(CL(I),D(I),I=1,3),IS
1    369    650 FORMAT(I5,6E10.0,I5)
1    370        IF(N)660,660,670
1    371    670 IF(IS)680,680,690
1    372    680 NN=N
1    373        IS=1
1    374        GOTO 700
1    375    690 READ(1,650)NN
1    376    700 DO 710 J=N,NN,IS
2    377        WRITE(2,720)J,(CL(I),D(I),I=1,3)
2    378    720 FORMAT(5X,I5,3(2X,F10.3,3X,F6.3))
2    379        LP=LP+1
2    380        IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
2    381        I=(K-1)*NE+J
2    382        DO 710 L=1,3
3    383        FE(I,2)=FE(I,2)+CL(L)*(XL(J)-D(L))**2*(2*D(L)+XL(J))/XL(J)**3
3    384        FE(I,3)=FE(I,3)+CL(L)*D(L)*(XL(J)-D(L))**2/XL(J)**2
3    385        FE(I,5)=FE(I,5)+CL(L)*D(L)**2*(3*XL(J)-2*D(L))/XL(J)**3
3    386        FE(I,6)=FE(I,6)-CL(L)*D(L)**2*(XL(J)-D(L))/XL(J)**2
3    387    710 CONTINUE
1    388        GOTO 730
1    389    660 CALL SPAC1
1    390 C JOINT LOADS
1    391        LP=LP+2
1    392        DO 741 N=1,5
```

```
D Line# 1      7                                  Microsoft FORTRAN77 V3.30 March 1
2    393       IF(MOD(LP+N,56))741,742,741
2    394    742 WRITE(2,999)FF
2    395       LP=LP+N
2    396       GOTO 743
2    397    741 CONTINUE
1    398    743 WRITE(2,740)
1    399    740 FORMAT(/3X'Joint Loads'//3X,
1    400       11X'LOADED'11X'HORIZONTAL'13X'VERTICAL'13X'EXTERNAL'/3X,
1    401       22X'JOINT'8X'LOAD-X (KN)  '10X'LOAD-Y (KN)'8X'MOM.-Z (KN-m)'/)
1    402       LP=LP+5
1    403       IF(MOD(LP,56).EQ.0)WRITE(2,999)FF
1    404    830 READ(1,750)J,(D(I),I=1,3),IS
1    405    750 FORMAT(I5,3E10.0,I5)
1    406       IF(J)760,760,770
1    407    770 IF(IS)780,780,790
1    408    780 JJ=J
1    409       IS=1
1    410       GOTO 800
1    411    790 READ(1,750)JJ
1    412    800 DO 810 N=J,JJ,IS
2    413       WRITE(2,840)N,(D(I),I=1,3)
2    414    840 FORMAT(5X,I5,3(9X,F12.4))
2    415       LP=LP+1
2    416       IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
2    417       DO 810 L=1,3
3    418       IF(JR(N,L))810,810,820
3    419    820 I=(K-1)*ND+JR(N,L)
3    420       Q(I)=Q(I)+D(L)
3    421    810 CONTINUE
1    422       GOTO 830
1    423    760 CALL SPAC1
1    424    525 CONTINUE
     425 C
     426 C READ & WRITE LOAD COMBINATION DATA
     427 C
     428       DO 850 I=1,NLC
1    429       DO 850 J=1,LC
2    430    850 F(I,J)=0.0
     431       DO 860 I=1,NLC
1    432       READ(1,'(A)')COM(I)
1    433    870 READ(1,750)K,F(I,K)
1    434       IF(K)860,860,870
1    435    860 CONTINUE
     436       WRITE(2,880)FF,(I,I=1,NLC)
     437    880 FORMAT(A,//3X'LOAD COMBINATION DATA'//3X,
     438       16X'LOAD COMBINATION NO./FACTORS'/3X'LC',10(I5,2X)/)
     439       LP=6
     440       DO 890 I=1,LC
1    441       WRITE(2,900)I,(F(J,I),J=1,NLC)
1    442    900 FORMAT(3X,I2,10(2X,F5.2))
1    443       LP=LP+1
1    444    890 IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
     445       WRITE(2,'(///)')
     446       LP=LP+3
     447       IF(MOD(LP,56).EQ.0)WRITE(2,999)FF
     448       DO 910 I=1,NLC
```

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D Line# 1      7                          Microsoft FORTRAN77 V3.30 March 1
1    449       WRITE(2,920)I,COM(I)
1    450       LP=LP+1
1    451    910 IF(MOD(LP,56).EQ.0)WRITE(2,999)FF
     452    920 FORMAT(3X'LOAD COMBINATION 'I5,3X,A/)
     453 C
     454 C READ & WRITE OUTPUT INFORMATION
     455 C
     456       CALL SPAC1
     457       LP=LP+2
     458       IF(MOD(LP,56).EQ.0)WRITE(2,999)FF
     459       DO 921 N=1,3
1    460       IF(MOD(LP+N,56))921,922,921
1    461    922 WRITE(2,999)FF
1    462       LP=LP+N
1    463       GOTO 923
1    464    921 CONTINUE
     465    923 WRITE(2,'(//3X,A/)')'OUTPUT INFORMATION'
     466       LP=LP+3
     467       IF(MOD(LP,56).EQ.0)WRITE(2,999)FF
     468       DO 930 I=1,5
1    469       READ(1,'(A)')CAS
1    470       WRITE(2,'(A)')CAS
1    471       LP=LP+1
1    472       IF(MOD(LP,56).EQ.0)WRITE(2,999)FF
1    473    950 READ(1,940)J,N,IS
1    474       WRITE(3,940)J,N,IS
1    475       IF(J)930,930,960
1    476    960 WRITE(2,940)J,N,IS
1    477       LP=LP+1
1    478       IF(MOD(LP,56).EQ.0)WRITE(2,999)FF
1    479       GOTO 950
1    480    930 CONTINUE
     481       CLOSE(3)
     482    940 FORMAT(3I5)
     483       CALL SPAC1
     484       LP=LP+2
     485       DO 941 N=1,6
1    486       IF(MOD(LP+N,56))941,942,941
1    487    942 WRITE(2,999)FF
1    488       LP=LP+N
1    489       GOTO 943
1    490    941 CONTINUE
     491    943 WRITE(2,970)ND,NB,NSU
     492    970 FORMAT(3X'SYSTEM DEGREES-OF-FREEDOM    ='I5/3X
     493       1          'BAND-WIDTH                 ='I5/3X
     494       2          'NO. OF SUPPORTED JOINTS    ='I5/)
     495        CALL SPAC1
     496 C
     497       CLOSE(1)
     498       CLOSE(2)
     499 C
     500 C RESOLVE APPLIED ACTIONS
     501 C
     502       OPEN(1,FILE='A:Q.GGG',ACCESS='DIRECT',FORM='FORMATTED',
     503      1  STATUS='NEW',RECL=15)
     504       DO 1185 I=1,ND*LC
```

```
D Line# 1      7                          Microsoft FORTRAN77 V3.30 March
1    505         WRITE(1,1130,REC=I)Q(I)
1    506   1185  Q(I)=0.0
     507         DO 1000 I=1,NE
1    508         DO 1000 J=1,6
2    509         IF(M(I,J))1000,1000,1010
2    510   1010  CALL TRANS(I)
2    511         JJ=M(I,J)
2    512         DO 1020 K=1,LC
3    513         DO 1030 L=1,6
4    514   1030  D(L)=0.0
3    515         DO 1040 L=1,6
4    516         DF=0.0
4    517         DO 1050 N=1,6
5    518   1050  DF=DF+XK(N,L)*FE((K-1)*NE+I,N)
4    519   1040  D(L)=DF
3    520   1020  Q((K-1)*ND+JJ)=Q((K-1)*ND+JJ)+D(J)
2    521   1000  CONTINUE
     522         DO 1060 I=1,ND*LC
1    523         READ(1,1130,REC=I)QQ
1    524   1060  Q(I)=QQ-Q(I)
     525         CLOSE(1,STATUS='DELETE')
     526 C
     527 C WRITE DATA FOR FURTHER ANALYSIS INTO FILE 2
     528 C
     529         FNOUT(1:2)=DR2
     530         FNOUT(3:2+6)='DANA.G'
     531         OPEN(2,FILE=FNOUT,ACCESS='DIRECT',FORM='UNFORMATTED',
     532        1  STATUS='NEW',RECL=102)
     533         WRITE(2,REC=1)NE,NJ,LC,ND,NB,NLC,NSU,NSS
     534         WRITE(2,REC=2)NS,E,G
     535         JJ=2
     536         DO 1120 I=1,NS
1    537   1120  WRITE(2,REC=I+JJ)(S(I,J),J=1,2)
     538         JJ=JJ+NS
     539         DO 1140 I=1,NE
1    540   1140  WRITE(2,REC=I+JJ)(MC(I,J),J=1,2),(M(I,J),J=1,6),MS(I)
     541         JJ=JJ+NE
     542         DO 1150 I=1,NJ
1    543   1150  WRITE(2,REC=I+JJ)(C(I,J),J=1,2)
     544         JJ=JJ+NJ
     545         DO 1160 I=1,NSU
1    546   1160  WRITE(2,REC=I+JJ)NSJ(I)
     547         JJ=JJ+NSU
     548         DO 1170 I=1,NE*LC
1    549   1170  WRITE(2,REC=I+JJ)(FE(I,J),J=2,3),(FE(I,J),J=5,6)
     550         JJ=JJ+NE*LC
     551         DO 1180 I=1,ND*LC
D 1  552   1180  WRITE(2,REC=I+JJ)Q(I)          Microsoft FORTRAN77 V3.30 M
     553         JJ=JJ+ND*LC
     554         DO 1190 I=1,NLC
1    555   1190  WRITE(2,REC=I+JJ)(F(I,J),J=1,LC)
     556         JJ=JJ+NLC
     557         DO 1210 I=1,NSS
1    558   1210  WRITE(2,REC=I+JJ)ISS(I),(SSS(I,J),J=1,3)
     559   1100  FORMAT(6E14.7)
     560         CLOSE(2)
     561         END
```

```
Name             Type      Offset  Class
A1               REAL      3354
A2               REAL      3386
A3               REAL      3418
AS               CHAR*1    2372
ATAN                               INTRINSIC
C                REAL         0    /JD     /
CAS              CHAR*50   3096
```

CHAR			INTRINSIC
CL	REAL	43264	/LD /
COM	CHAR*50	812	
COS			INTRINSIC
D	REAL	43276	/LD /
DF	REAL	1486	
DR1	CHAR*2	1320	
DR2	CHAR*2	1328	
E	REAL	1576	
F	REAL	42864	/LD /
FE	REAL	0	/LD /
FF	CHAR*1	1350	
FNINN	CHAR*10	1330	
FNOUT	CHAR*10	1340	
G	REAL	1580	
I	INTEGER*4	1470	
IABS			INTRINSIC
ID	INTEGER*4	1528	
IS	INTEGER*4	1478	
ISS	INTEGER*4	612	
J	INTEGER*4	1466	
JCO	INTEGER*4	1436	
JJ	INTEGER*4	2516	
JMFLAG	INTEGER*4	1432	
JR	INTEGER*4	1600	/JD /
K	INTEGER*4	2484	
KB	INTEGER*4	2964	
KK	INTEGER*4	2520	
L	INTEGER*4	1548	
LC	INTEGER*4	1648	
LP	INTEGER*4	2364	
M	INTEGER*4	6160	/ED /
MC	INTEGER*4	0	/ED /
MCO	INTEGER*4	1514	
MOD			INTRINSIC
MS	INTEGER*4	2880	/ED /
N	INTEGER*4	1482	
NB	INTEGER*4	2956	
ND	INTEGER*4	2952	
NE	INTEGER*4	1518	
NJ	INTEGER*4	1444	
NL	INTEGER*4	1506	
NLC	INTEGER*4	1652	

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D Line# 1     7                                  Microsoft FORTRAN77 V3.30 March
NN       INTEGER*4        2508
NS       INTEGER*4        1572
NSJ      INTEGER*4        4000    /JD     /
NSS      INTEGER*4        1552
NSU      INTEGER*4        1560
NT       INTEGER*4        1510
Q        REAL            20864    /LD     /
QQ       REAL             4328
RX       REAL             1490
RY       REAL             1494
S        REAL             4320    /ED     /
SN       CHAR*2           1326
SQRT                              INTRINSIC
SSS      REAL               12
TH       REAL             1440
TITLE    CHAR*80          1351
W        REAL             3350
XK       REAL                0    /TR     /
XL       REAL             4720    /ED     /


      564         SUBROUTINE SUBJC(TH,NL,NT,NJ,JMFLAG)
      565         COMMON /JD/C(200,2),JR(200,3),NSJ(60)
      566 C
      567 C GENERATES JOINT COORDINATE AUTOMATICALLY
      568 C
      569         JMFLAG=1
      570         READ(1,70)NL,NT,SPAN,TH,H
      571      70 FORMAT(2I5,3E10.0)
      572         XNL=SPAN/(NT-1)
      573         THR=TH*ATAN(1.0)/45.0
      574         K=1
      575         M2=NT*(NL-1)+1
      576         M3=NT
      577         IF(NL-NT)10,20,20
      578      10 M2=NL
      579         M3=1
      580      20 DO 30 I=1,M2,M3
    1 581         C(I,1)=-(K-1)*H*TAN(TH)
    1 582         C(I,2)=(K-1)*H
    1 583         N1=I+1
    1 584         N2=K*NT
    1 585         N3=1
    1 586         IF(NL-NT)40,50,50
    1 587      40 N1=I+NL
    1 588         N2=NL*(NT-1)+I
    1 589         N3=NL
    1 590      50 DO 60 J=N1,N2,N3
    2 591         C(J,1)=C(J-N3,1)+XNL
    2 592         C(J,2)=C(J-N3,2)
    2 593      60 CONTINUE
    1 594         K=K+1
    1 595      30 CONTINUE
      596         NJ=NT*NL
      597         RETURN
      598         END
```

D Line# 1 7 Microsoft FORTRAN77 V3.30 Marc

```
Name     Type         Offset P Class

ATAN                          INTRINSIC
C        REAL              0   /JD    /
H        REAL           4396
I        INTEGER*4      4432
J        INTEGER*4      4456
JMFLAG   INTEGER*4        16 *
JR       INTEGER*4      1600   /JD    /
K        INTEGER*4      4420
M2       INTEGER*4      4424
M3       INTEGER*4      4428
N1       INTEGER*4      4444
N2       INTEGER*4      4448
N3       INTEGER*4      4452
NJ       INTEGER*4        12 *
NL       INTEGER*4         4 *
NSJ      INTEGER*4      4000   /JD    /
NT       INTEGER*4         8 *
SPAN     REAL           4392
TAN                           INTRINSIC
TH       REAL              0 *
THR      REAL           4416
XNL      REAL           4412
```

```
      599       SUBROUTINE SUBMC(NL,NT,NE,JMFLAG)
      600           COMMON /ED/MC(360,2),MS(360),S(50,2),XL(360),M(360,6)
      601 C
      602 C GENERATES MEMBER CONNECTIVITY AUTOMATICALLY
      603 C
      604           IF(JMFLAG.EQ.1)GOTO 5
      605           READ(1,'(2I5)')NL,NT
      606         5 NH=NL
      607           NV=NT
      608           IF(NT-NL)20,20,10
      609        10 NH=NT
      610           NV=NL
      611        20 DO 30 I=1,NH
     1612           DO 30 J=1,NV-1
     2613           L=(I-1)*(NV-1)+J
     2614           MC(L,1)=(I-1)*NV+J
     2615           MC(L,2)=MC(L,1)+1
     2616        30 CONTINUE
      617           DO 40 I=1,NV
     1618           J1=I
     1619           DO 40 J=1,NH-1
     2620           L=(NV-1)*NH+(I-1)*(NH-1)+J
     2621           MC(L,1)=J1
     2622           J1=J1+NV
     2623           MC(L,2)=J1
     2624        40 CONTINUE
      625 C
      626           NE=(NT-1)*NL+(NL-1)*NT
      627 C
```

```
D Line# 1      7                                  Microsoft FORTRAN77 V3.30 Marc
     628 C READ & GENERATE ELEMENT SECTION NUMBER
     629 C
     630    140 READ(1,150)N,MS(N),IS
     631    150 FORMAT(3I5)
     632        IF(N)160,160,170
     633    170 IF(IS)140,140,180
     634    180 READ(1,150)NN
     635        DO 190 I=N+IS,NN,IS
1    636        MS(I)=MS(N)
1    637    190 CONTINUE
     638        GOTO 140
     639    160 RETURN
     640        END

Name     Type         Offset P Class

I        INTEGER*4      4476
IS       INTEGER*4      4512
J        INTEGER*4      4484
J1       INTEGER*4      4500
JMFLAG   INTEGER*4        12 *
L        INTEGER*4      4492
     M       INTEGER*4      6160    /ED     /
     MC      INTEGER*4         0    /ED     /
     MS      INTEGER*4      2880    /ED     /
     N       INTEGER*4      4508
     NE      INTEGER*4         8 *
     NH      INTEGER*4      4468
     NL      INTEGER*4         0 *
     NN      INTEGER*4      4522
     NT      INTEGER*4         4 *
     NV      INTEGER*4      4472
     S       REAL           4320    /ED     /
     XL      REAL           4720    /ED     /

          641        SUBROUTINE TRANS(I)
          642 C
          643 C FORM TRANSFORMATION MATRIX XK
          644 C
          645        COMMON /JD/C(200,2),JR(200,3),NSJ(60)
          646        COMMON /ED/MC(360,2),MS(360),S(50,2),XL(360),M(360,6)
          647        COMMON /TR/XK(6,6)
          648        J1=IABS(MC(I,1))
          649        J2=IABS(MC(I,2))
          650        X=C(J2,1)-C(J1,1)
          651        Y=C(J2,2)-C(J1,2)
          652        XL(I)=SQRT(X*X+Y*Y)
          653        IF(XL(I))10,10,20
          654     20 C1=X/XL(I)
          655        C2=Y/XL(I)
          656        DO 30 K=1,6
1         657        DO 30 L=1,6
2         658     30 XK(K,L)=0.0
          659        XK(1,1)=C1
          660        XK(2,2)=C1
```

```
D Line# 1      7                                  Microsoft FORTRAN77 V3.30 March
     661       XK(4,4)=C1
     662       XK(5,5)=C1
     663       XK(1,2)=C2
     664       XK(4,5)=C2
     665       XK(2,1)=-C2
     666       XK(5,4)=-C2
     667       XK(3,3)=1.0
     668       XK(6,6)=1.0
     669       RETURN
     670    10 WRITE(*,'(5X,A,I5,A,F15.4)')'Length of Element ',I,' = ',XL(I)
     671       RETURN
     672       END

Name     Type          Offset P Class

C        REAL               0   /JD     /
C1       REAL            4550
C2       REAL            4554
I        INTEGER*4          0 *
IABS                            INTRINSIC
J1       INTEGER*4       4534
J2       INTEGER*4       4538
JR       INTEGER*4       1600   /JD     /
K        INTEGER*4       4558
L        INTEGER*4       4562
M        INTEGER*4       6160   /ED     /
MC       INTEGER*4          0   /ED     /
MS       INTEGER*4       2880   /ED     /
NSJ      INTEGER*4       4000   /JD     /
S        REAL            4320   /ED     /
SQRT                            INTRINSIC
X        REAL            4542
XK       REAL               0   /TR     /
XL       REAL            4720   /ED     /
Y        REAL            4546

     673       SUBROUTINE SPAC1
     674       WRITE(2,10)('-',I=1,70)
     675    10 FORMAT(3X,70A1,/)
     676       RETURN
     677       END

Name     Type          Offset P Class

I        INTEGER*4       4566

     678

Name     Type            Size   Class

ED                      14800   COMMON
FRAME1                          PROGRAM
JD                       4240   COMMON
LD                      43300   COMMON
```

D Line# 1 7 Microsoft FORTRAN77 V3.30 March

SPAC1		SUBROUTINE
SUBJC		SUBROUTINE
SUBMC		SUBROUTINE
TR	144	COMMON
TRANS		SUBROUTINE

Pass One No Errors Detected
678 Source Lines

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```
D Line# 1      7                              Microsoft FORTRAN77 V3.30 March
       1 C
       2       PROGRAM FRAME2
       3 C
       4       CHARACTER DR*2,SN*2,FN*10
       5 C
       6       COMMON /ON/E,G
       7       COMMON /JD/C(200,2)                                    SSS(50,3),
       8       COMMON /ED/MC(360,2),MS(360),S(50,2),M(360,6),ISS(50),
       9       COMMON /LD/Q(5500),BK(21120)
      10 C                                                            RECL=6)
      11       OPEN(1,FILE='A:GRIL.DAT',ACCESS='DIRECT',FORM='FORMATTED',
      12       READ(1,10,REC=1)DR,SN
      13       CLOSE(1)
      14       FN(1:2)=DR
      15       FN(3:2+6)='DANA.G'
      16       FN(9:10)=SN
      17       OPEN(2,FILE=FN,ACCESS='DIRECT',FORM='UNFORMATTED',RECL=102)
      18       READ(2,REC=1)NE,NJ,LC,ND,NB,NLC,NSU,NSS
      19       READ(2,REC=2)NS,E,G
      20       JJ=2
      21       DO 40 I=1,NS
1     22    40 READ(2,REC=I+JJ)(S(I,J),J=1,2)
      23       JJ=JJ+NS
      24       DO 60 I=1,NE
1     25    60 READ(2,REC=I+JJ)(MC(I,J),J=1,2),(M(I,J),J=1,6),MS(I)
      26       JJ=JJ+NE
      27       DO 70 I=1,NJ
1     28    70 READ(2,REC=I+JJ)(C(I,J),J=1,2)
      29       JJ=JJ+NJ+NSU+NE*LC
      30       DO 80 I=1,ND*LC
1     31    80 READ(2,REC=I+JJ)Q(I)
      32       JJ=JJ+ND*LC+NLC
      33       DO 110 I=1,NSS
1     34   110 READ(2,REC=I+JJ)ISS(I),(SSS(I,J),J=1,3)
      35 C
      36       DO 90 I=1,ND*NB
1     37    90 BK(I)=0.0
      38       CALL ASS(ND,NB,NE,NSS)
      39       KC=1
      40       CALL SOLVER(ND,NB,LC,KC)
      41       IF(KC.LT.1)STOP
      42 C
      43       JJ=2+NS+NE+NJ+NSU+NE*LC
      44       DO 100 I=1,ND*LC
1     45   100 WRITE(2,REC=I+JJ)Q(I)
      46       CLOSE(2)
      47    10 FORMAT(2A)
      48    20 FORMAT(9I5)
      49    30 FORMAT(I5,2E14.7)
      50    50 FORMAT(4E14.7)
      51       END

Name     Type         Offset P Class

BK       REAL          22000   /LD     /
C        REAL              0   /JD     /
```

D Line# 1 7 Microsoft FORTRAN77 V3.30 March

DR	CHAR*2	12		
E	REAL	0	/ON	/
FN	CHAR*10	16		
G	REAL	4	/ON	/
I	INTEGER*4	66		
ISS	INTEGER*4	13360	/ED	/
J	INTEGER*4	74		
JJ	INTEGER*4	62		
KC	INTEGER*4	106		
LC	INTEGER*4	34		
M	INTEGER*4	4720	/ED	/
MC	INTEGER*4	0	/ED	/
MS	INTEGER*4	2880	/ED	/
NB	INTEGER*4	42		
ND	INTEGER*4	38		
NE	INTEGER*4	26		
NJ	INTEGER*4	30		
NLC	INTEGER*4	46		
NS	INTEGER*4	58		
NSS	INTEGER*4	54		
NSU	INTEGER*4	50		
Q	REAL	0	/LD	/
S	REAL	4320	/ED	/
SN	CHAR*2	14		
SSS	REAL	13560	/ED	/

```
      52        SUBROUTINE ASS(ND,NB,NE,NSS)                          SSS(50,3)
      53        COMMON /ED/MC(360,2),MS(360),S(50,2),M(360,6),ISS(50),A
      54        COMMON /LD/Q(5500),BK(21120)
      55        COMMON /ST/XK(6,6)
      56        INTEGER TC(6,6),TR(6,6)
      57 C
      58 C SYSTEM STIFFNESS MATRIX TRANSFORMATION
      59 C
      60        DO 10 I=1,NE
  1   61        CALL STIF(I,NSS)
  1   62        DO 20 K=1,6
  2   63        DO 20 L=1,6
  3   64        TC(K,L)=0
  3   65     20 TR(K,L)=0
  1   66        DO 30 K=1,6
  2   67        IF(M(I,K))30,30,40
  2   68     40 DO 50 L=1,6
  3   69        TC(K,L)=M(I,L)
  3   70     50 TR(L,K)=M(I,L)
  2   71     30 CONTINUE
  1   72        DO 60 J=1,6
  2   73        DO 60 K=1,6
  3   74        IF(TC(J,K))60,60,70
  3   75     70 L=TC(J,K)
  3   76        N=TR(J,K)
  3   77        IF(N-L)80,80,60
  3   78     80 JJ=L-N+1
  3   79        IF(JJ-NB)100,100,90
  3   80     90 WRITE(*,200)I,N
```

```
D Line# 1      7                                    Microsoft FORTRAN77 V3.30 March
3     81    100 BK((JJ-1)*ND+N)=BK((JJ-1)*ND+N)+XK(J,K)
3     82     60 CONTINUE
1     83     10 CONTINUE
      84        RETURN
      85    200 FORMAT(5X'Column > NB at Element'I5' Row'I5)
      86        END

Name     Type          Offset P Class

BK       REAL           22000    /LD     /
I        INTEGER*4        432
ISS      INTEGER*4      13360    /ED     /
J        INTEGER*4        448
JJ       INTEGER*4        456
K        INTEGER*4        440
L        INTEGER*4        444
M        INTEGER*4       4720    /ED     /
MC       INTEGER*4          0    /ED     /
MS       INTEGER*4       2880    /ED     /
N        INTEGER*4        452
NB       INTEGER*4          4 *
ND       INTEGER*4          0 *
NE       INTEGER*4          8 *
NSS      INTEGER*4         12 *
Q        REAL               0    /LD     /
S        REAL            4320    /ED     /
SSS      REAL           13560    /ED     /
TC       INTEGER*4        144
TR       INTEGER*4        288
XK       REAL               0    /ST     /


      87        SUBROUTINE STIF(I,NSS)
      88        COMMON /ON/E,G                                          SSS(50,3)
      89        COMMON /ED/MC(360,2),MS(360),S(50,2),M(360,6),ISS(50),^
      90        COMMON /ST/XK(6,6)
      91        COMMON /TR/TC(6,6),TR(6,6)
      92        COMMON /TW/XL
      93        DIMENSION SS(6)
      94 C
      95 C FORM ELEMENT MODEL
      96 C
      97        CALL TRANS(I)
      98        DO 10 K=1,6
1     99        DO 10 L=1,6
2    100     10 XK(K,L)=0.0
     101        L=MS(I)
     102        A=S(L,1)
     103        XI=S(L,2)
     104        IF(XL)20,20,30
     105     20 WRITE(*,300)I,XL
     106     30 AL=E*XI/XL**3
     107        IF(A)40,40,50
     108     40 WRITE(*,310)I,A
     109     50 IF(XI)60,60,70
     110     60 WRITE(*,320)I,XI
```

```
D Line# 1      7                                  Microsoft FORTRAN77 V3.30 March
     111     70 B=A*XL*XL/XI
     112        XK(1,1)=AL*B
     113        XK(4,4)=AL*B
     114        XK(1,4)=-AL*B
     115        XK(4,1)=-AL*B
     116        IF(MC(I,1).LT.0 .OR. MC(I,2).LT.0)GOTO 80
     117        XK(2,2)=12*AL
     118        XK(5,5)=12*AL
     119        XK(5,2)=-12*AL
     120        XK(2,5)=-12*AL
     121        XK(2,3)=6*XL*AL
     122        XK(3,2)=XK(2,3)
     123        XK(2,6)=XK(2,3)
     124        XK(6,2)=XK(2,3)
     125        XK(3,5)=-XK(2,3)
     126        XK(5,3)=XK(3,5)
     127        XK(5,6)=XK(3,5)
     128        XK(6,5)=XK(3,5)
     129        XK(3,3)=4*XL*XL*AL
     130        XK(6,6)=XK(3,3)
     131        XK(3,6)=XK(3,3)/2.0
     132        XK(6,3)=XK(3,6)
     133        GOTO 90
     134     80 XK(2,2)=3*AL
     135        XK(5,5)=3*AL
     136        XK(2,5)=-3*AL
     137        XK(5,2)=XK(2,5)
     138        IF(MC(I,1))110,100,120
     139    100 WRITE(*,330)I
     140    110 XK(2,6)=3*AL*XL
     141        XK(6,2)=XK(2,6)
     142        XK(5,6)=-XK(2,6)
     143        XK(6,5)=XK(5,6)
     144        XK(6,6)=XK(2,6)*XL
     145    120 IF(MC(I,2))140,130,90
     146    130 WRITE(*,330)I
     147    140 XK(2,3)=3*AL*XL
     148        XK(3,2)=XK(2,3)
     149        XK(3,5)=-XK(2,3)
     150        XK(5,3)=XK(3,5)
     151      - XK(3,3)=XK(2,3)*XL
     152     90 DO 150 K=1,6
   1 153        DO 150 L=1,6
   2 154        SUM=0.0
   2 155        DO 160 J=1,6
   3 156    160 SUM=SUM+XK(K,J)*TC(J,L)
   2 157    150 TR(K,L)=SUM
     158        DO 170 K=1,6
   1 159        DO 170 L=1,6
   2 160        SUM=0.0
   2 161        DO 180 J=1,6
   3 162    180 SUM=SUM+TC(J,K)*TR(J,L)
   2 163    170 XK(K,L)=SUM
     164        IF(NSS)420,420,430
     165    430 DO 340 J=1,NSS
   1 166        DO 410 K=1,6
```

```
D Line# 1      7                                  Microsoft FORTRAN77 V3.30 March
2    167    410 SS(K) = 0.0
1    168        IF(IABS(MC(I,1))-ISS(J))350,360,350
1    169    360 DO 370 K=1,3
2    170    370 SS(K)=SSS(J,K)
1    171    350 IF(IABS(MC(I,2))-ISS(J))340,380,340
1    172    380 DO 390 K=1,3
2    173    390 SS(K+3)=SSS(J,K)
1    174    340 CONTINUE
     175        DO 400 K=1,6
1    176    400 XK(K,K)=XK(K,K)+SS(K)
     177    420 CONTINUE
     178        RETURN
     179    300 FORMAT(5X'Length OF Element'I5' ='F15.4)
     180    310 FORMAT(5X'Area of Element'I5' ='E10.4)
     181    320 FORMAT(5X'Inertia of Element'I5' ='E10.4)
     182    330 FORMAT(5X'Element'I5'Connects to ZERO Joint')
     183        END

Name     Type          Offset P Class

A        REAL             532
AL       REAL             540
B        REAL             544
E        REAL               0    /ON     /
G        REAL               4    /ON     /
I        INTEGER*4          0 *
IABS                             INTRINSIC
ISS      INTEGER*4      13360    /ED     /
J        INTEGER*4        552
K        INTEGER*4        524
L        INTEGER*4        528
M        INTEGER*4       4720    /ED     /
MC       INTEGER*4          0    /ED     /
MS       INTEGER*4       2880    /ED     /
NSS      INTEGER*4          4 *
S        REAL            4320    /ED     /
SS       REAL             500
SSS      REAL           13560    /ED     /
SUM      REAL             548
TC       REAL               0    /TR     /
TR       REAL             144    /TR     /
XI       REAL             536
XK       REAL               0    /ST     /
XL       REAL               0    /TW     /

     184        SUBROUTINE TRANS(I)
     185 C
     186 C FORM TRANSFORMATION MATRIX
     187 C
     188        COMMON /JD/C(200,2)                                        SSS(50,3)
     189        COMMON /ED/MC(360,2),MS(360),S(50,2),M(360,6),ISS(50),^
     190        COMMON /TR/TC(6,6),TR(6,6)
     191        COMMON /TW/XL
     192        J1=IABS(MC(I,1))
     193        J2=IABS(MC(I,2))
```

```
D Line# 1      7                                  Microsoft FORTRAN77 V3.30 March
     194       X=C(J2,1)-C(J1,1)
     195       Y=C(J2,2)-C(J1,2)
     196       XL=SQRT(X*X+Y*Y)
     197       IF(XL)10,10,20
     198    20 C1=X/XL
     199       C2=Y/XL
     200       DO 30 K=1,6
1    201       DO 30 L=1,6
2    202    30 TC(K,L)=0.0
     203       TC(1,1)=C1
     204       TC(2,2)=C1
     205       TC(4,4)=C1
     206       TC(5,5)=C1
     207       TC(1,2)=C2
     208       TC(4,5)=C2
     209       TC(2,1)=-C2
     210       TC(5,4)=-C2
     211       TC(3,3)=1.0
     212       TC(6,6)=1.0
     213       RETURN
     214    10 WRITE(*,'(5X,A,I5,A,F15.4)')'Length of Element ',I,' = ',XL
     215       RETURN
     216       END

Name     Type         Offset P Class

C        REAL              0   /JD     /
C1       REAL            720
C2       REAL            724
I        INTEGER*4         0 *
IABS                         INTRINSIC
ISS      INTEGER*4     13360   /ED     /
J1       INTEGER*4       704
J2       INTEGER*4       708
K        INTEGER*4       728
L        INTEGER*4       732
M        INTEGER*4      4720   /ED     /
MC       INTEGER*4         0   /ED     /
MS       INTEGER*4      2880   /ED     /
S        REAL           4320   /ED     /
SQRT                         . INTRINSIC
SSS      REAL          13560   /ED     /
TC       REAL              0   /TR     /
TR       REAL            144   /TR     /
X        REAL            712
XL       REAL              0   /TW     /
Y        REAL            716

     217       SUBROUTINE SOLVER(ND,NB,LC,KC)
     218       COMMON /LD/Q(5500),BK(21120)
     219 C
     220 C TRIPLE MATRIX DECOMPOSITION TECHNIQUE
     221 C
     222       DO 600 I=1,ND
1    223       IF(BK(I))600,1060,600
```

```
D Line# 1      7                                  Microsoft FORTRAN77 V3.30 March
1    224    600 CONTINUE
       225        DO 650 I=2,ND
1    226        IL1=I-1
1    227        NBL=IL1+NB
1    228        IF(NBL-ND)615,615,610
1    229    610 NBL=ND
1    230    615 DO 650 J=I,NBL
2    231        IJ=(J-I)*ND+I
2    232        SUM=BK(IJ)
2    233        NNB=J-NB+1
2    234        IF(NNB)620,620,630
2    235    620 NNB=1
2    236    630 IF(NNB-IL1)632,632,642
2    237    632 DO 640 N=NNB,IL1
3    238    640 SUM=SUM-BK((I-N)*ND+N)*BK((J-N)*ND+N)/BK(N)
2    239    642 BK(IJ)=SUM
2    240    650 CONTINUE
       241        DO 666 II=1,LC
1    242        LI=ND*(II-1)
1    243        Q(LI+1)=Q(LI+1)/BK(1)
1    244        DO 665 I=2,ND
2    245        IR=LI+I
2    246        SUM=Q(IR)
2    247        I1=I-1
2    248        NNB=I-NB+1
2    249        IF(NNB)655,655,656
2    250    655 NNB=1
2    251    656 DO 662 K=NNB,I1
3    252        KR=LI+K
3    253        SUM=SUM-BK((I-K)*ND+K)*Q(KR)
3    254    662 CONTINUE
2    255    665 Q(IR)=SUM/BK(I)
1    256    666 CONTINUE
       257        DO 680 II=1,LC
1    258        LI=ND*(II-1)
1    259        DO 675 JJ=2,ND
2    260        I=ND-JJ+1
2    261        IR=LI+I
2    262        SUM=0.0
2    263        I1=I+1
2    264        NNB=I-1+NB
2    265        IF(NNB-ND)672,672,671
2    266    671 NNB=ND
2    267    672 DO 673 K=I1,NNB
3    268        KR=LI+K
3    269    673 SUM=SUM+BK((K-I)*ND+I)*Q(KR)
2    270    675 Q(IR)=Q(IR)-SUM/BK(I)
1    271    680 CONTINUE
       272        RETURN
       273   1060 WRITE(*,'(A)')'ZERO Leading Coefficient Encountered'
       274        KC=0
       275        RETURN
       276        END

Name     Type         Offset P Class
```

D Line# 1 7 Microsoft FORTRAN77 V3.30 March

BK	REAL	22000	/LD	/
I	INTEGER*4	736		
I1	INTEGER*4	804		
II	INTEGER*4	784		
IJ	INTEGER*4	764		
IL1	INTEGER*4	748		
IR	INTEGER*4	800		
J	INTEGER*4	756		
JJ	INTEGER*4	824		
K	INTEGER*4	808		
KC	INTEGER*4	12	*	
KR	INTEGER*4	816		
LC	INTEGER*4	8	*	
LI	INTEGER*4	792		
N	INTEGER*4	776		
NB	INTEGER*4	4	*	
NBL	INTEGER*4	752		
ND	INTEGER*4	0	*	
NNB	INTEGER*4	772		
Q	REAL	0	/LD	/
SUM	REAL	768		

Name	Type	Size	Class
ASS			SUBROUTINE
ED		14160	COMMON
FRAME2			PROGRAM
JD		1600	COMMON
LD		40944	COMMON
ON		8	COMMON
SOLVER			SUBROUTINE
ST		144	COMMON
STIF			SUBROUTINE
TR		288	COMMON
TRANS			SUBROUTINE
TW		4	COMMON

Pass One No Errors Detected
276 Source Lines

```
D Line# 1      7                          Microsoft FORTRAN77 V3.30 March
       1 C
       2 C
       3       PROGRAM FRAME3
       4 C
       5       CHARACTER DR*2,SN*2,FN*10
       6 C
       7       COMMON /ON/E,G
       8       COMMON /JD/C(200,2),NSJ(60)
       9       COMMON /ED/MC(360,2),MS(360),S(50,2),M(360,6)
      10       COMMON /RS/P(600,3)
      11       DIMENSION F(10)
      12 C                                                          RECL=6)
      13       OPEN(1,FILE='A:GRIL.DAT',ACCESS='DIRECT',FORM='FORMATTED',^
      14       READ(1,10,REC=1)DR,SN
      15       CLOSE(1)
      16       FN(1:2)=DR
      17       FN(3:2+6)='DANA.G'
      18       FN(9:10)=SN
      19       OPEN(2,FILE=FN,ACCESS='DIRECT',FORM='UNFORMATTED',RECL=102)
      20       READ(2,REC=1)NE,NJ,LC,ND,NB,NLC,NSU
      21       READ(2,REC=2)NS,E,G
      22       JJ=2
      23       DO 1120 I=1,NS
1     24  1120 READ(2,REC=I+JJ)(S(I,J),J=1,2)
      25       JJ=JJ+NS
      26       DO 1140 I=1,NE
1     27  1140 READ(2,REC=I+JJ)(MC(I,J),J=1,2),(M(I,J),J=1,6),MS(I)
      28       JJ=JJ+NE
      29       DO 1150 I=1,NJ
1     30  1150 READ(2,REC=I+JJ)(C(I,J),J=1,2)
      31       JJ=JJ+NJ
      32       DO 1160 I=1,NSU
1     33  1160 READ(2,REC=I+JJ)NSJ(I)
      34 C
      35       CALL EFORCE(ND,NE,LC,NJ,NS,NSU)
      36 C
      37       CALL JFORCE(NSU,NE,NJ,LC,NS)
      38 C
      39       FN(3:2+6)='JFOR.G'
      40       OPEN(3,FILE=FN,ACCESS='DIRECT',STATUS='NEW',RECL=420)
      41       DO 2100 I=1,NSU
1     42  2100 WRITE(3,REC=I)((P((K-1)*NSU+I,J),J=1,3),K=1,LC)
      43       CLOSE(2)
      44       CLOSE(3)
      45 C
      46    10 FORMAT(2A)
      47  1100 FORMAT(9I5)
      48  1110 FORMAT(I5,10E14.7)
      49  1130 FORMAT(12E14.7)
      50       END

Name     Type         Offset P Class

C       REAL              0   /JD     /
DR      CHAR*2           52
E       REAL              0   /ON     /
```

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D Line# 1 7 Microsoft FORTRAN77 V3.30 March

F	REAL	12		
FN	CHAR*10	56		
G	REAL	4	/ON	/
I	INTEGER*4	102		
J	INTEGER*4	110		
JJ	INTEGER*4	98		
K	INTEGER*4	138		
LC	INTEGER*4	74		
M	INTEGER*4	4720	/ED	/
MC	INTEGER*4	0	/ED	/
MS	INTEGER*4	2880	/ED	/
NB	INTEGER*4	82		
ND	INTEGER*4	78		
NE	INTEGER*4	66		
NJ	INTEGER*4	70		
NLC	INTEGER*4	86		
NS	INTEGER*4	94		
NSJ	INTEGER*4	1600	/JD	/
NSU	INTEGER*4	90		
P	REAL	0	/RS	/
S	REAL	4320	/ED	/
SN	CHAR*2	54		

```
      SUBROUTINE EFORCE(ND,NE,LC,NJ,NS,NSU)
C
      COMMON /ED/MC(360,2),MS(360),S(50,2),M(360,6)
      COMMON /RS/P(600,3) /FF/FE(6)
      COMMON /ST/XK(6,6) /TR/T(6,6) /DD/DT(6),D(6)
      DIMENSION DG(6)
      OPEN(3,FILE='MFRCS.PNN',ACCESS='DIRECT',FORM='FORMATTED',
     1          STATUS='NEW',RECL=168)
C
      DO 110 KK=1,LC
      DO 110 I=(KK-1)*NE+1,KK*NE
      DO 120 K=1,6
  120 D(K)=0.0
      I1=I-(KK-1)*NE
C
C GLOBAL DISPLACEMENT TRANSFORMATION
C
      JJ=2+NS+NE+NJ+NSU+LC*NE
      DO 130 K=1,6
      IF(M(I1,K))130,130,140
  140 L=M(I1,K)
      READ(2,REC=(KK-1)*ND+L+JJ)D(K)
  130 CONTINUE
C
C LOCAL DISPLACEMENT TRANSFORMATION
C
      CALL TRANS(I1)
      DO 280 J=1,6
      DG(J)=D(J)
      SUM=0.0
      DO 290 K=1,6
  290 SUM=SUM+T(J,K)*D(K)
```

```
D Line# 1      7                              Microsoft FORTRAN77 V3.30 March
3     83    280 DT(J)=SUM
2     84 C
2     85 C COMPUTATION OF ELEMENT FORCES
2     86 C
2     87        CALL STIF(I1)
2     88        JJ=2+NS+NE+NJ+NSU
2     89        READ(2,REC=I+JJ)(FE(J),J=2,3),(FE(J),J=5,6)
2     90        DO 160 J=1,6
3     91        SUM=0.0
3     92        DO 170 K=1,6
4     93    170 SUM=SUM+XK(J,K)*DT(K)
3     94    160 D(J)=SUM+FE(J)
2     95        WRITE(2,REC=I+JJ)(D(J),J=1,6),(DT(J),J=1,6)
2     96        WRITE(3,1130,REC=I)(D(J),D(J+3),J=1,3),(DG(J),DG(J+3),J=1,3)
2     97    110 CONTINUE
      98   1130 FORMAT(12E9.2)
      99        CLOSE(3)
     100        RETURN
     101        END

Name     Type          Offset P Class

D        REAL             24   /DD     /
DG       REAL            174
DT       REAL              0   /DD     /
FE       REAL              0   /FF     /
I        INTEGER*4       206
I1       INTEGER*4       218
J        INTEGER*4       230
JJ       INTEGER*4       222
K        INTEGER*4       214
KK       INTEGER*4       198
L        INTEGER*4       226
LC       INTEGER*4         8 *
M        INTEGER*4      4720   /ED     /
MC       INTEGER*4         0   /ED     /
MS       INTEGER*4      2880   /ED     /
ND       INTEGER*4         0 *
NE       INTEGER*4         4 *
NJ       INTEGER*4        12 *
NS       INTEGER*4        16 *
NSU      INTEGER*4        20 *
P        REAL              0   /RS     /
S        REAL           4320   /ED     /
SUM      REAL            234
T        REAL              0   /TR     /
XK       REAL              0   /ST     /

     102        SUBROUTINE JFORCE(NSU,NE,NJ,LC,NS)
     103 C
     104        COMMON /ED/MC(360,2),MS(360),S(50,2),M(360,6)
     105        COMMON /RS/P(600,3) /DD/DT(6),D(6)
     106        COMMON /JD/C(200,2),NSJ(60) /TR/T(6,6)
     107 C
     108 C
```

```
D Line# 1      7                          Microsoft FORTRAN77 V3.30 March
     109 C COMPUTATION OF JOINT FORCES
     110 C
     111       JJ=2+NS+NE+NJ+NSU
     112       DO 300 J=1,NSU
1    113       DO 300 I=1,NE
2    114       IF(IABS(MC(I,1))-NSJ(J))310,320,310
2    115    320 CALL TRANS(I)
2    116       DO 322 N=1,LC
3    117       READ(2,REC=(N-1)*NE+I+JJ,ERR=1000)(D(L),L=1,6)
3    118       DO 324 L=1,3
4    119       SUM=0.0
4    120       DO 326 K=1,3
5    121    326 SUM=SUM+T(K,L)*D(K)
4    122    324 P((N-1)*NSU+J,L)=P((N-1)*NSU+J,L)+SUM
3    123    322 CONTINUE
2    124    310 IF(IABS(MC(I,2))-NSJ(J))300,340,300
2    125    340 CALL TRANS(I)
2    126       DO 342 N=1,LC
3    127       READ(2,REC=(N-1)*NE+I+JJ,ERR=1000)(D(L),L=1,6)
3    128       DO 344 L=1,3
4    129       SUM=0.0
4    130       DO 346 K=1,3
5    131    346 SUM=SUM+T(K,L)*D(K+3)
4    132    344 P((N-1)*NSU+J,L)=P((N-1)*NSU+J,L)+SUM
3    133    342 CONTINUE
2    134    300 CONTINUE
     135       RETURN
     136   1000 WRITE(*,'(A,I5)')' ERROR IN READING FILE 3 ',I
     137   1230 FORMAT(12E14.7)
     138       RETURN
     139       END

 Name     Type          Offset P Class

 C        REAL               0   /JD     /
 D        REAL              24   /DD     /
 DT       REAL               0   /DD     /
 I        INTEGER*4        266
 IABS                              INTRINSIC
 J        INTEGER*4        258
 JJ       INTEGER*4        254
 K        INTEGER*4        294
 L        INTEGER*4        282
 LC       INTEGER*4         12 *
 M        INTEGER*4       4720   /ED     /
 MC       INTEGER*4          0   /ED     /
 MS       INTEGER*4       2880   /ED     /
 N        INTEGER*4        274
 NE       INTEGER*4          4 *
 NJ       INTEGER*4          8 *
 NS       INTEGER*4         16 *
 NSJ      INTEGER*4       1600   /JD     /
 NSU      INTEGER*4          0 *
 P        REAL               0   /RS     /
 S        REAL            4320   /ED     /
 SUM      REAL             290
```

D Line# 1 7 Microsoft FORTRAN77 V3.30 March
T REAL 0 /TR /

```
      140       SUBROUTINE TRANS(I)
      141 C
      142 C FORM TRANSFORMATION MATRIX
      143 C
      144       COMMON /JD/C(200,2),NSJ(60)
      145       COMMON /ED/MC(360,2),MS(360),S(50,2),M(360,6)
      146       COMMON /TR/T(6,6)
      147       J1=IABS(MC(I,1))
      148       J2=IABS(MC(I,2))
      149       X=C(J2,1)-C(J1,1)
      150       Y=C(J2,2)-C(J1,2)
      151       XL=SQRT(X*X+Y*Y)
      152       IF(XL)10,10,20
      153    20 C1=X/XL
      154       C2=Y/XL
      155       DO 30 K=1,6
1     156       DO 30 L=1,6
2     157    30 T(K,L)=0.0
      158       T(1,1)=C1
      159       T(2,2)=C1
      160       T(4,4)=C1
      161       T(5,5)=C1
      162       T(1,2)=C2
      163       T(4,5)=C2
      164       T(2,1)=-C2
      165       T(5,4)=-C2
      166       T(3,3)=1.0
      167       T(6,6)=1.0
      168       RETURN
      169    10 WRITE(*,'(5X,A,I5,A,F15.4)')'Length of Element ',I,' = ',XL
      170       RETURN
      171       END
```

Name	Type	Offset	P	Class
C	REAL	0		/JD /
C1	REAL	332		
C2	REAL	336		
I	INTEGER*4	0	*	
IABS				INTRINSIC
J1	INTEGER*4	312		
J2	INTEGER*4	316		
K	INTEGER*4	340		
L	INTEGER*4	344		
M	INTEGER*4	4720		/ED /
MC	INTEGER*4	0		/ED /
MS	INTEGER*4	2880		/ED /
NSJ	INTEGER*4	1600		/JD /
S	REAL	4320		/ED /
SQRT				INTRINSIC
T	REAL	0		/TR /
X	REAL	320		
XL	REAL	328		

```
D Line# 1     7                          Microsoft FORTRAN77 V3.30 March
Y      REAL            324


     172        SUBROUTINE STIF(I)
     173 C
     174        COMMON /ON/E,G
     175        COMMON /ED/MC(360,2),MS(360),S(50,2),M(360,6)
     176        COMMON /ST/XK(6,6)
     177        COMMON /JD/C(200,2),NSJ(60)
     178 C
     179 C FORM ELEMENT MODEL
     180 C
     181        K=IABS(MC(I,1))
     182        J=IABS(MC(I,2))
     183        XL=SQRT((C(J,1)-C(K,1))**2+(C(J,2)-C(K,2))**2)
     184        DO 10 K=1,6
1    185        DO 10 L=1,6
2    186     10 XK(K,L)=0.0
     187        L=MS(I)
     188        A=S(L,1)
     189        XI=S(L,2)
     190        IF(XL)20,20,30
     191     20 WRITE(*,300)I,XL
     192     30 AL=E*XI/XL**3
     193        IF(A)40,40,50
     194     40 WRITE(*,310)I,A
     195     50 IF(XI)60,60,70
     196     60 WRITE(*,320)I,XI
     197     70 B=A*XL*XL/XI
     198        XK(1,1)=AL*B
     199        XK(4,4)=AL*B
     200        XK(1,4)=-AL*B
     201        XK(4,1)=-AL*B
     202        IF(MC(I,1).LT.0 .OR. MC(I,2).LT.0)GOTO 80
     203        XK(2,2)=12*AL
     204        XK(5,5)=12*AL
     205        XK(5,2)=-12*AL
     206        XK(2,5)=-12*AL
     207        XK(2,3)=6*XL*AL
     208        XK(3,2)=XK(2,3)
     209        XK(2,6)=XK(2,3)
     210        XK(6,2)=XK(2,3)
     211        XK(3,5)=-XK(2,3)
     212        XK(5,3)=XK(3,5)
     213        XK(5,6)=XK(3,5)
     214        XK(6,5)=XK(3,5)
     215        XK(3,3)=4*XL*XL*AL
     216        XK(6,6)=XK(3,3)
     217        XK(3,6)=XK(3,3)/2.0
     218        XK(6,3)=XK(3,6)
     219        GOTO 90
     220     80 XK(2,2)=3*AL
     221        XK(5,5)=3*AL
     222        XK(2,5)=-3*AL
     223        XK(5,2)=XK(2,5)
     224        IF(MC(I,1))110,100,120
```

```
D Line# 1      7                              Microsoft FORTRAN77 V3.30 March
     225   100 WRITE(*,330)I
     226   110 XK(2,6)=3*AL*XL
     227       XK(6,2)=XK(2,6)
     228       XK(5,6)=-XK(2,6)
     229       XK(6,5)=XK(5,6)
     230       XK(6,6)=XK(2,6)*XL
     231   120 IF(MC(I,2))140,130,90
     232   130 WRITE(*,330)I
     233   140 XK(2,3)=3*AL*XL
     234       XK(3,2)=XK(2,3)
     235       XK(3,5)=-XK(2,3)
     236       XK(5,3)=XK(3,5)
     237       XK(3,3)=XK(2,3)*XL
     238    90 RETURN
     239   300 FORMAT(5X'Length OF Element'I5' ='F15.4)
     240   310 FORMAT(5X'Area of Element'I5' ='E10.4)
     241   320 FORMAT(5X'Inertia of Element'I5' ='E10.4)
     242   330 FORMAT(5X'Element'I5'Connects to ZERO Joint')
     243       END

Name     Type          Offset P Class

A        REAL             364
AL       REAL             372
B        REAL             376
C        REAL               0   /JD     /
E        REAL               0   /ON     /
G        REAL               4   /ON     /
I        INTEGER*4          0 *
IABS                           INTRINSIC
J        INTEGER*4        352
K        INTEGER*4        348
L        INTEGER*4        360
M        INTEGER*4       4720   /ED     /
MC       INTEGER*4          0   /ED     /
MS       INTEGER*4       2880   /ED     /
NSJ      INTEGER*4       1600   /JD     /
S        REAL            4320   /ED     /
SQRT                           INTRINSIC
XI       REAL             368
XK       REAL               0   /ST     /
XL       REAL             356


Name     Type            Size   Class

DD                         48   COMMON
ED                      13360   COMMON
EFORCE                         SUBROUTINE
FF                         24   COMMON
FRAME3                         PROGRAM
JD                       1840   COMMON
JFORCE                         SUBROUTINE
ON                          8   COMMON
RS                       7200   COMMON
```

```
D Line# 1      7
ST                                144    COMMON
STIF                                     SUBROUTINE
TR                                144    COMMON
TRANS                                    SUBROUTINE

 Pass One      No Errors Detected
               243 Source Lines
```

```
D Line# 1      7                          Microsoft FORTRAN77 V3.30 March
       1 C
       2 C
       3       PROGRAM FRAME4
       4 C
       5       CHARACTER DR1*2,SN*2,FN*10,FF*1,DR2*2,C2,EN*2,EF*2,DN*2,DF*2
       6 C
       7       COMMON /ED/MC(360,2)  /RS/NSJ(60) /JD/JR(200,3) /FF/F(10,10)
       8       COMMON /PP/EN,EF,DN,DF
       9 C                                                          RECL=6)
      10       OPEN(1,FILE='A:GRIL.DAT',ACCESS='DIRECT',FORM='FORMATTED', ^
      11       READ(1,10,REC=1)DR2,SN,DR1
      12       CLOSE(1,STATUS='DELETE')
      13       FN(1:2)=DR2
      14       FN(3:2+6)='DANA.G'
      15       FN(9:10)=SN
      16       OPEN(1,FILE=FN,ACCESS='DIRECT',FORM='UNFORMATTED',RECL=102)
      17       FN(3:2+6)='JFOR.G'
      18       OPEN(4,FILE=FN,ACCESS='DIRECT',RECL=420)
      19       FN(1:2)=DR1
      20       FN(3:2+6)='INFO.G'
      21       OPEN(3,FILE=FN)
      22       FN(3:2+6)='RESU.G'
      23       OPEN(2,FILE=FN,STATUS='NEW')
      24 C
      25       READ(1,REC=1)NE,NJ,LC,ND,NB,NLC,NSU
      26       READ(1,REC=2)NS
      27       FF=CHAR(12)
      28       DO 20 I=1,NJ
    1 29    20 READ(3,1100)(JR(I,J),J=1,3)
      30          JJ=2+NS
      31          DO 30 I=1,NE
    1 32    30 READ(1,REC=I+JJ)(MC(I,J),J=1,2)
      33          JJ=JJ+NE+NJ
      34          DO 50 I=1,NSU
    1 35    50 READ(1,REC=I+JJ)NSJ(I)
      36          JJ=JJ+NSU+NE*LC+ND*LC
      37          DO 40 I=1,NLC
    1 38    40 READ(1,REC=I+JJ)(F(I,J),J=1,LC)
      39 C
      40          C2=CHAR(27)
      41          EN(1:1)=C2
      42          EF(1:1)=C2
      43          DN(1:1)=C2
      44          DF(1:1)=C2
      45          EN(2:2)='E'
      46          EF(2:2)='F'
      47          DN(2:2)='G'
      48          DF(2:2)='H'
      49 C
      50          CALL GDIS(NE,NJ,NSU,ND,LC,NLC,NS,FF)
      51          CALL LDIS(NE,NJ,LC,NLC,NS,NSU,FF)
      52          CALL EFORCE(NE,NJ,LC,NLC,NSU,NS,FF)
      53          CALL REACT(NE,NJ,LC,NLC,NSU,NS,FF)
      54          CALL CACTION(NE,NJ,LC,NLC,NSU,NS,FF)
      55 C
      56          CLOSE(1)
```

```
D Line# 1      7                          Microsoft FORTRAN77 V3.30 March
      57       CLOSE(2)
      58       CLOSE(3,STATUS='DELETE')
      59       CLOSE(4,STATUS='DELETE')
      60    10 FORMAT(3A)
      61  1100 FORMAT(915)
      62  1130 FORMAT(10E14.7)
      63       END

Name     Type          Offset P Class

C2       CHAR*1            94
CHAR                                INTRINSIC
DF       CHAR*2             6    /PP     /
DN       CHAR*2             4    /PP     /
DR1      CHAR*2            16
DR2      CHAR*2            12
EF       CHAR*2             2    /PP     /
EN       CHAR*2             0    /PP     /
F        REAL               0    /FF     /
FF       CHAR*1            60
FN       CHAR*10           18
I        INTEGER*4         62
J        INTEGER*4         70
JJ       INTEGER*4         78
JR       INTEGER*4          0    /JD     /
LC       INTEGER*4         36
MC       INTEGER*4          0    /ED     /
NB       INTEGER*4         44
ND       INTEGER*4         40
NE       INTEGER*4         28
NJ       INTEGER*4         32
NLC      INTEGER*4         48
NS       INTEGER*4         56
NSJ      INTEGER*4          0    /RS     /
NSU      INTEGER*4         52
SN       CHAR*2            14

      64          SUBROUTINE GDIS(NE,NJ,NSU,ND,LC,NLC,NS,FF)
      65 C
      66 C  PRINT GLOBAL DISPLACEMENTS
      67 C
      68        CHARACTER FF,EN*2,EF*2,DN*2,DF*2
      69        COMMON /JD/JR(200,3)  /DD/D(12),DT(12) /FF/F(10,10)
      70        COMMON /PP/EN,EF,DN,DF
      71        WRITE(2,1000)FF,EN,DN,EF,DF
      72        CALL SPAC
      73        LP=4
      74        JJ=2+NS+NE+NJ+NSU+NE*LC
      75     10 READ(3,1010)J,N,IS
      76        IF(J)100,100,110
      77    110 DO 111 K=1,3
      78        IF(MOD(LP+K,56))111,112,111
1     79    112 WRITE(2,'(A)')FF
1     80        LP=LP+K
1     81        GOTO 113
```

```
D Line# 1      7                                  Microsoft FORTRAN77 V3.30 March
1     82    111 CONTINUE
      83    113 WRITE(2,1030)EN,DN,EF,DF
      84        LP=LP+3
      85        DO 20 L=J,N,IS
1     86        DO 20 I=1,NLC
2     87        DO 30 K=1,3
3     88     30 D(K)=0.0
2     89        DO 40 KK=1,LC
3     90        IF(F(I,KK))50,40,50
3     91     50 DO 60 K=1,3
4     92        IF(JR(L,K))60,60,70
4     93     70 II=JR(L,K)
4     94        READ(1,REC=(KK-1)*ND+II+JJ)QQ
4     95        D(K)=D(K)+QQ*F(I,KK)*1000.0
4     96     60 CONTINUE
3     97     40 CONTINUE
2     98        IF(I-1)80,90,80
2     99     90 WRITE(2,1040)L,I,(D(K),K=1,3)
2    100        LP=LP+1
2    101        IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
2    102        GOTO 20
2    103     80 WRITE(2,1050)I,(D(K),K=1,3)
2    104        LP=LP+1
2    105        IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
2    106     20 CONTINUE
     107        CALL SPAC
     108        LP=LP+2
     109        IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
     110        GOTO 10
     111    100 CALL SPAC
     112        RETURN
     113   1000 FORMAT(3A,//5X'GLOBAL DISPLACEMENTS'2A)
     114   1010 FORMAT(3I5)
     115   1020 FORMAT(6E14.7)
     116   1030 FORMAT(2A,3X'JOINT'12X'LOAD'3X'X - MOVEMENT'3X'Y - MOVEMENT'
     117       1'Z - ROTATION'/5X'NO.'5X'COMBINATION'4X'    (mm)     '7X'(mm)'
     118       28X'1.0E-3 rad.'/2A)
     119   1040 FORMAT(3X,I5,11X,I5,3(3X,F12.4))
     120   1050 FORMAT(19X,I5,3(3X,F12.4))
     121        END

Name     Type          Offset P Class

D        REAL               0   /DD     /
DF       CHAR*2             6   /PP     /
DN       CHAR*2             4   /PP     /
DT       REAL              48   /DD     /
EF       CHAR*2             2   /PP     /
EN       CHAR*2             0   /PP     /
F        REAL               0   /FF     /
FF       CHAR*1            28 *
         INTEGER*4        152
II       INTEGER*4        168
IS       INTEGER*4        132
J        INTEGER*4        124
JJ       INTEGER*4        120
```

```
D Line# 1     7                              Microsoft FORTRAN77 V3.30 March
JR       INTEGER*4          0   /JD    /
K        INTEGER*4        136
KK       INTEGER*4        160
L        INTEGER*4        140
LC       INTEGER*4         16 *
LP       INTEGER*4        116
  MOD                          INTRINSIC
N        INTEGER*4        128
ND       INTEGER*4         12 *
NE       INTEGER*4          0 *
NJ       INTEGER*4          4 *
NLC      INTEGER*4         20 *
NS       INTEGER*4         24 *
NSU      INTEGER*4          8 *
QQ       REAL             172
```

```
      SUBROUTINE LDIS(NE,NJ,LC,NLC,NS,NSU,FF)
C
C PRINT ELEMENT END DISPLACEMENTS
C
      CHARACTER FF,EN*2,EF*2,DN*2,DF*2
      COMMON /ED/MC(360,2) /DD/D(12),DT(12)  /FF/F(10,10)
      COMMON /PP/EN,EF,DN,DF
      DIMENSION DU(6)
      WRITE(2,1000)FF,EN,DN,EF,DF
      CALL SPAC
      LP=4
      JJ=2+NS+NE+NJ+NSU
  120 READ(3,1010)J,N,IS
      IF(J)130,130,140
  140 DO 111 K=1,3
1     IF(MOD(LP+K,56))111,112,111
1 112 WRITE(2,'(A)')FF
1     LP=LP+K
1     GOTO 113
1 111 CONTINUE
  113 WRITE(2,1030)EN,DN,EF,DF
      LP=LP+3
      DO 150 L=J,N,IS
1     DO 150 I=1,NLC
2     DO 160 K=1,6
3 160 D(K)=0.0
2     DO 170 KK=1,LC
3     IF(F(I,KK))180,170,180
3 180 READ(1,REC=(KK-1)*NE+L+JJ)(DU(K),K=1,6),(DT(K),K=1,6)
3     DO 190 K=1,6
4 190 D(K)=D(K)+DT(K)*F(I,KK)*1000.0
3 170 CONTINUE
2     IF(I-1)200,210,200
2 210 WRITE(2,1040)L,I,MC(L,1),(D(K),K=1,3)
2     LP=LP+1
2     IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
2     GOTO 220
2 200 WRITE(2,1050)I,MC(L,1),(D(K),K=1,3)
2     LP=LP+1
```

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```
D Line# 1      7                                  Microsoft FORTRAN77 V3.30 March
2    161       IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
2    162    220 WRITE(2,1060)MC(L,2),(D(K),K=4,6)
2    163       LP=LP+1
2    164       IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
2    165    150 CONTINUE
     166       CALL SPAC
     167       LP=LP+2
     168       IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
     169       GOTO 120
     170    130 CALL SPAC
     171       RETURN
     172   1000 FORMAT(3A,//5X'ELEMENT - END  DISPLACEMENTS'2A)
     173   1010 FORMAT(3I5)
     174   1020 FORMAT(84X,6E14.7)
     175   1030 FORMAT(2A,3X'ELEMENT'4X'LOAD'3X'JOINT'3X'X - MOVEMENT'3X
     176      1'Y - MOVEMENT'3X'Z - ROTATION'/4X'NUMBER'3X'COMB.',5X
     177      2'NO.'4X'    (mm)     '7X'(mm)'8X'1.0E-3 rad'/2A)
     178   1040 FORMAT(5X,I5,3X,I5,3X,I5,3(3X,F12.4))
     179   1050 FORMAT(13X,I5,3X,I5,3(3X,F12.4))
     180   1060 FORMAT(21X,I5,3(3X,F12.4))
     181       END

Name     Type         Offset P Class

D        REAL              0   /DD     /
DF       CHAR*2            6   /PP     /
DN       CHAR*2            4   /PP     /
DT       REAL             48   /DD     /
DU       REAL            422
EF       CHAR*2            2   /PP     /
EN       CHAR*2            0   /PP     /
F        REAL              0   /FF     /
FF       CHAR*1           24 *
I        INTEGER*4       482
IS       INTEGER*4       462
J        INTEGER*4       454
JJ       INTEGER*4       450
K        INTEGER*4       466
KK       INTEGER*4       490
L        INTEGER*4       470
LC       INTEGER*4         8 *
LP       INTEGER*4       446
MC       INTEGER*4         0   /ED     /
MOD                            INTRINSIC
N        INTEGER*4       458
NE       INTEGER*4         0 *
NJ       INTEGER*4         4 *
NLC      INTEGER*4        12 *
NS       INTEGER*4        16 *
NSU      INTEGER*4        20 *

     182       SUBROUTINE EFORCE(NE,NJ,LC,NLC,NSU,NS,FF)
     183 C
     184 C PRINT ELEMENT END FORCES
     185 C
```

```
D Line# 1      7                                  Microsoft FORTRAN77 V3.30 March
     186       CHARACTER FF,EN*2,EF*2,DN*2,DF*2
     187       COMMON /ED/MC(360,2) /DD/D(12),DT(12)  /FF/F(10,10)
     188       COMMON /PP/EN,EF,DN,DF
     189       WRITE(2,1000)FF,EN,DN,EF,DF
     190       CALL SPAC
     191       LP=4
     192       JJ=2+NS+NE+NJ+NSU
     193   120 READ(3,1010)J,N,IS
     194       IF(J)130,130,140
     195   140 DO 111 K=1,3
1    196       IF(MOD(LP+K,56))111,112,111
1    197   112 WRITE(2,'(A)')FF
1    198       LP=LP+K
1    199       GOTO 113
1    200   111 CONTINUE
     201   113 WRITE(2,1030)EN,DN,EF,DF
     202       LP=LP+3
     203       DO 150 L=J,N,IS
1    204       DO 150 I=1,NLC
2    205       DO 160 K=1,6
3    206   160 D(K)=0.0
2    207       DO 170 KK=1,LC
3    208       IF(F(I,KK))180,170,180
3    209   180 READ(1,REC=(KK-1)*NE+L+JJ)(DT(K),K=1,6)
3    210       DO 190 K=1,6
4    211   190 D(K)=D(K)+DT(K)*F(I,KK)
3    212   170 CONTINUE
2    213       IF(I-1)200,210,200
2    214   210 WRITE(2,1040)L,I,MC(L,1),(D(K),K=1,3)
2    215       LP=LP+1
2    216       IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
2    217       GOTO 220
2    218   200 WRITE(2,1050)I,MC(L,1),(D(K),K=1,3)
2    219       LP=LP+1
2    220       IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
2    221   220 WRITE(2,1060)MC(L,2),(D(K),K=4,6)
2    222       LP=LP+1
2    223       IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
2    224   150 CONTINUE
     225       CALL SPAC
     226       LP=LP+2
     227       IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
     228       GOTO 120
     229   130 CALL SPAC
     230       RETURN
     231  1000 FORMAT(3A,//5X'ELEMENT - END FORCES'2A)
     232  1010 FORMAT(3I5)
     233  1020 FORMAT(6E14.7)
     234  1030 FORMAT(2A,3X'ELEMENT'4X'LOAD'3X'JOINT'4X'  AXIAL - X'6X'SHEAR
     235     15X'MOMENT - Z'/4X'NUMBER'3X'COMB.'5X'NO.'6X'    KN'12X'KN'11X
     236     2'KN - m'/2A)
     237  1040 FORMAT(5X,I5,3X,I5,3X,I5,3(3X,F12.4))
     238  1050 FORMAT(13X,I5,3X,I5,3(3X,F12.4))
     239  1060 FORMAT(21X,I5,3(3X,F12.4))
     240       END
```

```
D Line# 1      7                                    Microsoft FORTRAN77 V3

Name     Type          Offset P Class

D        REAL               0   /DD     /
DF       CHAR*2             6   /PP     /
DN       CHAR*2             4   /PP     /
DT       REAL              48   /DD     /
EF       CHAR*2             2   /PP     /
EN       CHAR*2             0   /PP     /
F        REAL               0   /FF     /
FF       CHAR*1            24 *
I        INTEGER*4        854
IS       INTEGER*4        834
J        INTEGER*4        826
JJ       INTEGER*4        822
K        INTEGER*4        838
KK       INTEGER*4        862
L        INTEGER*4        842
LC       INTEGER*4          8 *
LP       INTEGER*4        818
MC       INTEGER*4          0   /ED     /
MOD                             INTRINSIC
N        INTEGER*4        830
NE       INTEGER*4          0 *
NJ       INTEGER*4          4 *
NLC      INTEGER*4         12 *
NS       INTEGER*4         20 *
NSU      INTEGER*4         16 *


     241          SUBROUTINE REACT(NE,NJ,LC,NLC,NSU,NS,FF)
     242 C
     243 C  PRINT SUPPORT REACTIONS
     244 C
     245          CHARACTER FF,EN*2,EF*2,DN*2,DF*2
     246          COMMON /JD/JR(200,3)  /DD/D(12),DT(12) /FF/F(10,10)
     247          COMMON /RS/NSJ(60) /PP/EN,EF,DN,DF
     248          DIMENSION DF(30)
     249          WRITE(2,1000)FF,EN,DN,EF,DF
     250          CALL SPAC
     251          LP=4
     252       10 READ(3,1010)J,N,IS
     253          IF(J)100,100,110
     254      110 DO 111 K=1,3
1    255          IF(MOD(LP+K,56))111,112,111
1    256      112 WRITE(2,'(A)')FF
1    257          LP=LP+K
1    258          GOTO 113
1    259      111 CONTINUE
     260      113 WRITE(2,1030)EN,DN,EF,DF
     261          LP=LP+3
     262          DO 150 L=J,N,IS
1    263          DO 70 K=1,NSU
2    264          IF(L-NSJ(K))70,140,70
2    265      140 II=K
2    266          GOTO 130
```

```
D Line# 1      7                          Microsoft FORTRAN77 V3.30 March
2    267     70 CONTINUE
1    268        GOTO 150
1    269    130 READ(4,REC=II)(DP(K),K=1,3*LC)
1    270        DO 20 I=1,NLC
2    271        DO 30 K=1,3
3    272     30 D(K)=0.0
2    273        DO 40 KK=1,LC
3    274        IF(F(I,KK))50,40,50
3    275     50 DO 60 K=1,3
4    276     60 D(K)=D(K)+DP((KK-1)*3+K)*F(I,KK)
3    277     40 CONTINUE
2    278        IF(I-1)80,90,80
2    279     90 WRITE(2,1040)L,I,(D(K),K=1,3)
2    280        LP=LP+1
2    281        IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
2    282        GOTO 20
2    283     80 WRITE(2,1050)I,(D(K),K=1,3)
2    284        LP=LP+1
2    285        IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
2    286     20 CONTINUE
1    287    150 CONTINUE
     288        CALL SPAC
     289        LP=LP+2
     290        IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
     291        GOTO 10
     292    100 CALL SPAC
     293        RETURN
     294   1000 FORMAT(3A,//5X'SUPPORT REACTIONS'2A)
     295   1010 FORMAT(3I5)
     296   1020 FORMAT(5X,10E14.7)
     297   1030 FORMAT(2A,3X'JOINT'12X'LOAD'5X' FORCE - X'6X'FORCE - Y'5X
     298       1'MOMENT - Z'/5X'NO.'5X'COMBINATION'6X'     KN'12X'KN'11X
     299       2'KN - m'/2A)
     300   1040 FORMAT(3X,I5,11X,I5,3(3X,F12.4))
     301   1050 FORMAT(19X,I5,3(3X,F12.4))
     302        END

Name     Type          Offset P Class

D        REAL               0   /DD     /
DF       CHAR*2             6   /PP     /
DN       CHAR*2             4   /PP     /
DP       REAL            1142
DT       REAL              48   /DD     /
EF       CHAR*2             2   /PP     /
EN       CHAR*2             0   /PP     /
F        REAL               0   /FF     /
FF       CHAR*1            24 *
I        INTEGER*4       1306
II       INTEGER*4       1298
IS       INTEGER*4       1274
         INTEGER*4       1266
JR       INTEGER*4          0   /JD     /
K        INTEGER*4       1278
KK       INTEGER*4       1314
L        INTEGER*4       1282
```

```
D Line# 1     7                              Microsoft FORTRAN77 V3.30 March
LC      INTEGER*4          8 *
LP      INTEGER*4       1262
MOD                             INTRINSIC
N       INTEGER*4       1270
NE      INTEGER*4          0 *
NJ      INTEGER*4          4 *
NLC     INTEGER*4         12 *
NS      INTEGER*4         20 *
NSJ     INTEGER*4          0    /RS     /
NSU     INTEGER*4         16 *


      303       SUBROUTINE CACTION(NE,NJ,LC,NLC,NSU,NS,FF)
      304 C
      305 C COMPARE ELEMENT ACTIONS & PRINT
      306 C
      307       CHARACTER FF,EN*2,EF*2,DN*2,DF*2
      308       COMMON /BB/IB(2,6),LL(360),A(360,6),B(2,6)
      309       COMMON /DD/D(12),DT(12) /FF/F(10,10) /PP/EN,EF,DN,DF
      310 C
      311       WRITE(2,1700)FF,EN,DN,EF,DF
      312       CALL SPAC
      313       LP=4
      314       II=2+NS+NE+NJ+NSU
      315   100 READ(3,1100)J,N,IS
      316       IF(J)20,20,10
      317    10 DO 111 K=1,3
    1 318       IF(MOD(LP+K,56))111,112,111
    1 319   112 WRITE(2,'(A)')FF
    1 320       LP=LP+K
    1 321       GOTO 113
    1 322   111 CONTINUE
      323   113 WRITE(2,1000)EN,DN,J,N,IS,EF,DF
      324       CALL SPAC
      325       LP=LP+3
      326       DO 211 K=1,3
    1 327       IF(MOD(LP+K,56))211,212,211
    1 328   212 WRITE(2,'(A)')FF
    1 329       LP=LP+K
    1 330       GOTO 213
    1 331   211 CONTINUE
      332   213 WRITE(2,1200)EN,DN,EF,DF
      333       LP=LP+3
      334       DO 30 I=1,NLC
    1 335       JJ=0
    1 336       DO 40 L=J,N,IS
    2 337       DO 50 K=1,6
    3 338    50 D(K)=0.0
    2 339       DO 60 KK=1,LC
    3 340       IF(F(I,KK))70,60,70
    3 341    70 READ(1,REC=(KK-1)*NE+L+II)(DT(K),K=1,6)
    3 342       DO 80 K=1,6
    4 343    80 D(K)=D(K)+DT(K)*F(I,KK)
    3 344    60 CONTINUE
    2 345       JJ=JJ+1
    2 346       LL(JJ)=L
```

```
D Line# 1      7                                  Microsoft FORTRAN77 V3.30 Marc
2    347       DO 90 K=1,6
3    348    90 A(JJ,K)=D(K)
2    349    40 CONTINUE
1    350       CALL MACTION(JJ)
1    351       WRITE(2,1400)I,(B(1,K),IB(1,K),K=1,3)
1    352       LP=LP+1
1    353       IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
1    354       WRITE(2,1500)(B(2,K),IB(2,K),K=1,3)
1    355       LP=LP+1
1    356       IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
1    357       WRITE(2,1600)(B(1,K),IB(1,K),K=4,6)
1    358       LP=LP+1
1    359       IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
1    360       WRITE(2,1500)(B(2,K),IB(2,K),K=4,6)
1    361       LP=LP+1
1    362       IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
1    363    30 CONTINUE
     364       CALL SPAC
     365       LP=LP+2
     366       IF(MOD(LP,56).EQ.0)WRITE(2,'(A)')FF
     367       GOTO 100
     368    20 CALL SPAC
     369       RETURN
     370  1000 FORMAT(2A,3X'COMPARISON OF FORCES ALONG ELEMENTS 'I4' THRU '
     371      1' AT STEP 'I4,2A)
     372  1100 FORMAT(3I5)
     373  1200 FORMAT(2A,4X'LOAD'3X'ELEM'8X'Max/Min'3X'On'2(7X'Max/Min'3X'O
     374      1'COMB'4X'END'4X'  AXIAL - X'2X'EL.'5X'SHEAR - Y'2X'EL.'4X
     375      2'MOMENT - Z'2X'EL.'/2A)
     376  1300 FORMAT(6E14.7)
     377  1400 FORMAT(3X,I5,2X'A-End'3X,3(F12.2,1X,I4,2X))
     378  1500 FORMAT(18X,3(F12.2,1X,I4,2X))
     379  1600 FORMAT(10X'B-End'3X,3(F12.2,1X,I4,2X))
     380  1700 FORMAT(3A,//3X'COMPARISON OF ELEMENT-END FORCES'2A)
     381       END

Name     Type          Offset P Class

A        REAL            1488   /BB     /
B        REAL           10128   /BB     /
D        REAL               0   /DD     /
DF       CHAR*2             6   /PP     /
DN       CHAR*2             4   /PP     /
DT       REAL              48   /DD     /
EF       CHAR*2             2   /PP     /
EN       CHAR*2             0   /PP     /
F        REAL               0   /FF     /
FF       CHAR*1            24 *
I        INTEGER*4       1584
IB       INTEGER*4          0   /BB     /
II       INTEGER*4       1564
JS       INTEGER*4       1576
J        INTEGER*4       1568
JJ       INTEGER*4       1592
K        INTEGER*4       1580
KK       INTEGER*4       1608
```

```
L       INTEGER*4       1596
LC      INTEGER*4          8 *
LL      INTEGER*4         48    /BB     /
LP      INTEGER*4       1560
MOD                             INTRINSIC
N       INTEGER*4       1572
NE      INTEGER*4          0 *
NJ      INTEGER*4          4 *
NLC     INTEGER*4         12 *
NS      INTEGER*4         20 *
NSU     INTEGER*4         16 *
```

```
    382         SUBROUTINE MACTION(N)
    383 C
    384 C FINDS THE MAX/MIN OF FORCES & THEIR POSITIONS
    385 C
    386         COMMON /BB/IB(2,6),LL(360),A(360,6),B(2,6)
    387         DIMENSION IP(2,6)
    388 C
    389         DO 10 J=1,6
1   390         XMAX=A(1,J)
1   391         IMAX=1
1   392         XMIN=A(1,J)
1   393         IMIN=1
1   394         DO 20 I=1,N
2   395         IF(XMIN-A(I,J))40,40,30
2   396      30 XMIN=A(I,J)
2   397         IMIN=I
2   398      40 IF(XMAX-A(I,J))50,20,20
2   399      50 XMAX=A(I,J)
2   400         IMAX=I
2   401      20 CONTINUE
1   402         B(1,J)=XMAX
1   403         B(2,J)=XMIN
1   404         IP(1,J)=IMAX
1   405         IP(2,J)=IMIN
1   406      10 CONTINUE
    407         DO 60 I=1,2
1   408         DO 60 J=1,6
2   409         IMAX=IP(I,J)
2   410      60 IB(I,J)=LL(IMAX)
    411         RETURN
    412         END
```

```
Name     Type          Offset P Class

A       REAL            1488    /BB     /
B       REAL           10128    /BB     /
I       INTEGER*4       2070
IB      INTEGER*4          0    /BB     /
IMAX    INTEGER*4       2058
IMIN    INTEGER*4       2066
IP      INTEGER*4       2002
J       INTEGER*4       2050
LL      INTEGER*4         48    /BB     /
```

```
        INTEGER*4          0 *
XMAX    REAL            2054
XMIN    REAL            2062


    413         SUBROUTINE SPAC
    414         CHARACTER*2 EN,EF,DN,DF
    415         COMMON /PP/EN,EF,DN,DF
    416         WRITE(2,10)EN,DN,('-',I=1,70),EF,DF
    417      10 FORMAT(2A,3X,70A1,/2A)
    418         RETURN
    419         END

Name     Type          Offset P Class

DF       CHAR*2             6   /PP     /
DN       CHAR*2             4   /PP     /
EF       CHAR*2             2   /PP     /
EN       CHAR*2             0   /PP     /
         INTEGER*4       2078


Name     Type            Size   Class

BB                      10176   COMMON
CACTID                          SUBROUTINE
DD                         96   COMMON
ED                       2880   COMMON
EFORCE                          SUBROUTINE
FF                        400   COMMON
FRAME4                          PROGRAM
GDIS                            SUBROUTINE
JD                       2400   COMMON
LDIS                            SUBROUTINE
MACTID                          SUBROUTINE
PP                          8   COMMON
REACT                           SUBROUTINE
RS                        240   COMMON
SPAC                            SUBROUTINE

 Pass One     No Errors Detected
              419 Source Lines
```

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