CAD PACKAGE FOR DESIGN OF RCC COLUMNS

A DISSERTATION

submitted in partial fulfilment of the
requirements for the award of the degree
of
MASTER OF ENGINEERING
in
CIVIL ENGINEERING
(With Specialization in Building Science and Technology)

By

ANJAN BHUSHAN

DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF ROORKEE
ROORKEE–247 667 (INDIA)

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CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in the dissertation entiled **"CAD PACKAGE FOR DESIGN OF RCC COLUMNS"** in partial fulfilment of requirements for the award of **Master of Engineering** with specialization in **"Building Science and Technology"**, submitted in the Department of Civil Engineering, University of Roorkee, Roorkee is an authentic record of my work carried out during a period from July 1997 to March 1998 under the supervision of **Dr. S.K. Kaushik** and **Dr . N.M. Bhandari** both Professors, Department of Civil Engineering, University of Roorkee, Roorkee, India.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree or diploma.

Anjan Bhushan

Date : March,31 1998

(ANJAN BHUSHAN)

Roorkee

This is to certity that the above statement is correct to the best of our knowledge and belief.

N Bhandari 31.3.98

(Dr. N.M. BHANDARI)
Professor
Deptt. of Civil Engg.
University of Roorkee
Roorkee - 247 667
(U.P.) India

31/3/98

(Dr. S.K. KAUSHIK)
Professor
Deptt. of Civil Engg.
University of Roorkee
Roorkee - 247 667
(U.P.) India

ABSTRACT

Generally design pakcages of RCC columns based on assumption of neutral axis, neither consider biaxial slender column nor braced case of column. This is due to the fact that analysis of biaxial slender column is quite complex. Design charts of SP:16 tackle this problem with less difficulty. That's why it's a popular tool in designer community.

A package based on design charts need inclusion of the charts in program and programming of an input device either keyboard or mouse to enter the value from design charts.

In the present work, a software based upon design requirements of IS: 456 and SP: 16 design charts has been developed. Limit state method of design was chosen for the work. Software is user friendly and provides a pleasent environment for programming. Graphics and sound were used to create desired effect. After deigning the section software draws a cross-section of it.

The major hurdle was to develop a methodology to read data from design charts. This was overcome, by first digitzing the charts and then their programming in graphics mode to display it on monitor. To read data from these charts programming of mouse was done. Mouse programming is a new feature of present work. It was being done with the help of low level programming facilities of 'C' language. Software was developed on Turbo C compiler on DOS platform.

Comparison of results of solved examples of standard books and results from software validates the effort of present work.

CONTENTS

CHAPTER - 1

INTRODUCTION

1.1 GENERAL

It may be a debatable topic whether automation have generated employment or worsen the scenario of umemployment. But the help it has provided to mankind is not a topic of discussion. Automation of any process needs identitying steps in that process involved. An important point should be kept in mind, only repetetive processes can be translated as automatic process. Automation provides tools having potential of fast calculations & decisions making under numerous constraints and maintains precision in a particular job. It almost nullify the factor `human error'. Software development or programming is a part of general term automation.

Design of a particular problem involves well defind steps and conditions. Each design problem should pass to the constraints prescribed. Therefore, numerous COMPUTER AIDED DESIGN (CAD) packages are floating in market. In structural engineering almost all institutions and firms have their own packages. STADD III is a popolar structual analysis and design package available in market.

Almost each student have some methematical programs of their own. One step further, institutions have some good programs for analysis as well design. But, by and Large, there exists a wide gap between `programs' of institutions and commercial `pacakages' available in market. The difference is so much that by saying `program' we visualize any tool for solving a problem while `software package' give us an idea of graphics user interface, interative programming use of mouse, sound and much more. In this era of liberalisations students should be encouraged to market their software. It will strengththen institution industry relation as well. So, what we need is to provide same competative enviorment to the user. This CAD pacakage is a humble step in this direction.

1.2 CAPABILITIES AND LIMITATIONS OF THE PACKAGE

1. It considers all cases of compression and bending provided by SP16.
2. Takes into account for rectangular and circular columns both.
3. Considers braced case - in single and double curvature.
4. Draw a coloured diagram of cross-section of column.
5. Don't considers cases of arial tension and/or bending.
6. It can be modified easily to make it more user friendly and to include case 1.2.5.
7. It considers slenderness effect also.

1.3 ORGANISATION OF THESIS WORK

The thesis is being organised under following heading.

Chapter 1 Introduction It provides and overall view of the work being done.

Literature Review is being done in chapter 2. It provides different methods of analysis and design of columns. Then it review some previous work done and relavance of present work.

Chapter 3 discusses features of CAD Package progamming lauguage, compiler and hardware used for development of software. A detailed plan of software with flow of control & data details. It also includes flow-charts and block diagram at the end.

Typical Input and Output from program is given in chapter 4.

In chapter 5 conclusions are being compiled.

CHAPTER - 2

LITERATURE REVIEW

2.1 GENERAL

In present work design of columns for axial, uniaxial and biaxial cases for rectangular and circular columns are being done. Literature review consists of various approaches of analysis and design and previous works done in past.

2.2 AXIALLY LOADED COLUMNS

In limit state design the ultimate load carrying capacity of the section is given by following equation.

For mild steel

$$Pu = 0.446\ fck\ Ac + 0.87\ fy\ As$$

$$= 0.446\ fck\ Dx\ Dy + (0.87\ fy - 0.446\ fck)\ As$$

For high strength deformed bars

$$Pu = 0.466\ fck\ Ac + 0.75\ fy\ As$$

$$= 0.466\ fck\ Ag + (0.75\ fy - 0.446\ fck)\ As$$

However with minimum ecentricity criteria of code

$$Pu = 0.4\ fck\ Ac + 0.67\ fy\ Asc$$

can be taken for both cases in safer side

2.3 UNIAXIAL BENDING OF COLUMNS

The design of column section for axial load and uniaxial moment can be made by preassigning the section and then checking its adequecy. The adequecy of the section may be checked by assuming the the position of neutral axis. Then the strain profile can be established on the failure criteria of the column section and the corresponding strain profile for conrete and steel can be determined from their stress-strain curves. The axial force and moment capacity of section can be computed which should satisfy the requirement that the internal axial force is acting at the same ecentricity at that of external load. the computation of axial load and moment capacity of the section for an assumed position of neutral axis can be made by establishing strain profile based on the failure criteria of column section. Figures 2.1 & 2.2 shows the position of neutral axis outside and within the section and the corresponding strain profiles respectively. The strain diagrams for concrete and steel can be determined from their design stress strain curves.

For neutral axis lying outside the section the axial load capacity can be determined as follows.

$$Pu = Cc + Cs$$

The moment capacity can be determined by taking the moment of forces about the centre of the section as follows

$$Mu = Cc\,(0.5D - Yc) + \sum Csi\ Ysi$$

where,

Cc = Compressive force in concrete

$$= 0.446\ fck\ BDg - \frac{2}{3} \cdot \frac{4}{7} BD = 4.46\ fck\ BD - \frac{4}{21} gBD$$

g = Difference between the stress at the highest compressed edge and stress at the least compressed edge.

$$= 0.446\ fck \left(\frac{4D/7}{kD-3D/7} \right)^2 = 0.446\ fck \left(\frac{4}{7k-3} \right)^2$$

$$Cc = 0.446\ fck\ BD \left[1 - \left(\frac{4}{21} \cdot \frac{4}{7k-3} \right)^2 \right]$$

$$= Cc\ fck\ BD$$

$$Cs = \sum Asi\,(fsci - fcci)$$

fsci = Stress in reinforcement i

fcci = Stress in concret at the level of reinforcement

Asi = Area of reinforcement

Y_c = Distance of centroid of compressive force in concretc from the most com pressed edge of the section

$$= \frac{\text{Moment of the compressive force in concretc from the most compressed edge}}{\text{compressive force in concrete}}$$

$$= \frac{0.446\ fck\ \ BD\ \ 0.05\ D - \left(\frac{4}{21} \right) gD \left(\frac{3}{7} D + \frac{3}{4} \quad \frac{4}{3} D \right)}{0.446\ fck\ BD - gD/21}$$

$$= \frac{0.223\ fck\ BD^2 - 8g\ BD^2 / 49}{0.446\ fck\ BD - 4gBD/21} = y_c^1 D$$

$$y_c^1 = \frac{0.223\ fck - 8\ g / 4\ g}{0.446\ fck - 4g / 21}$$

y_{si} = Distance of reinforcement from the x-x axis

P_u = $C^1 fck\ BD + \Sigma\ Asi\ (\ fsci - fcci\ )$

M_u = $C^1 fck\ BD\ (\ 0.5\ D - y_c^1 D\ ) + \Sigma\ Asi\ (\ fsci - fcci\ )\ Ysi$

The values of coefficients $C_C^1 = C_c / f_{ck}\ BD$ & $y_c^1 = y_c / D$ for different values of k is given in table 2.1

For neutral axis lying within the section the axial load capacity can be determined as follows

$$P_u = C_c + C_s - T_s$$

The moment capacity of the section can be determined by taking the moment of forces about the centre of the section as follows.

$$M_u = C_c\ (\ 0.50\ D - y_c\ ) + \Sigma\ C_{si}\ y_{sci} + \Sigma\ T_{si}\ y_{sti}$$

$$= 0.446\ f_{ck}\ Bx_u\ (\ 0.5\ D - y_c\ ) + \Sigma\ Asci\ (\ fsci - fcci\ )\ y_{sci} + \Sigma\ A_{sti}\ y_{sti}$$

where,

C_c = Compressive force in concrete

C_{si} = Compressive force in compression steel i

= $A_{sci}\ (\ f_{sci} - f_{cci}\ )$

A_{sci} = Area of compression reinforcement i

f_{sci} = Stress in compression reinforcement i

f_{cci} = Stress in concerte at the level of compression reinforcement i

T_s = Tansile force in tension reinforcement

= $\Sigma A_{si} f_{sti}$

y_c = Distance of centroid of compressive force in concrete from the most compressed edge of the section

= $0.416 X_u$

y_{sci} = Distance of compression reinforcement i from the centre of the section

y_{sti} = Distance of tension reinforcement i from the centre of the section.

P_a = $0.446 f_{ck} BX_u + \Sigma A_{sci} (f_{sci} - f_{sci}) - \Sigma A_{sti} f_{sti}$

M_u = $0.446 f_{ck} BX_u (0.5D - 0.416 X_u) + A_{sci} (f_{sci} - f_{cci}) y_{sci} + \Sigma A_{sti} f_{sti} y_{sti}$

2.4 BIAXIAL BENDING

Concrete is a non linear material and the non - linearlity increases when a biaxial bending case is encountered.

2.4.1 Approximate Methods of Analysis & Design

The design of the section can be made more effectively with the help of the interaction surface for load versus moment as shown in Fig.2.3. It consists of series of interaction curves obtained by varying the inclination of neutral axis. Any typical point b on the interaction surface represents the failure load and moments P_{ub}, M_{uxb} and M_{uyb}. A typical horizontal section taken through the interaction surface gives the interaction line for the ultimate moments M_{ux} and M_{uy} at ultimate load P_u. One such interaction line is shown in Fig.2.4. It is a constant load contour of the interaction surface and its shape depends on the geometry of the section, strength of materials, area of steel and its arrangement, and value of the axial load (Sinha, 1996).

The design of section based on the actual interaction surface requires consideration of large number of variables to cover all possible design cases that gives rise to large number of charts. As the equation of such curves are complex and can not be obtain easily, the design of the section is made based on the simplifying approximations for the shape of the interaction surface (Park and Paulay, 1975).

Various suggestions have been made for the shape of the interaction surface from which, knowing the uniaxial strengths, biaxial strengths may be calculated. Some of approximate failure surfaces have been discussed in following sections.

2.4.2 Bresler's Reciprocal Load Method

This approach due to Bresler (1960) provides a very simple expression for the axial load capacity of a reinforced concrete columns under biaxial bending.

Bresler utilized the failure surface S_1 ($1/P_u$, e_x, e_y) to develop an expression for the determination of ultimate axial load capacity of a column under biaxially applied bending moments. This failure surface S1 is shown in Fig.2.5. The expression approximates the ordinate $1/P'_u$ lying on the plane S'_1 ($1/P'_u$, e_x, e_y) passing through characteristic points A, B and C as indicated in the figure. Based on the above approximation, the strength of the biaxially loaded column section is given by,

$$\frac{1}{P_u} = \frac{1}{P'_u} = \frac{1}{P_{ox}} + \frac{1}{P_{oy}} - \frac{1}{P_{uz}} \qquad (2.4.1)$$

where,

P_u = Ultimate load capacity of the column under biaxial eccetricities e_x & e_y

P_{ox} = Ultimate load capacity under uniaxial eccentricity e_y

P_{oy} = Ultimate load capacity under uniaxial eccentricity e_x

P_{uz} = Ultimate concentric load capacity of the column section

This expression is quite simple in form and variables involved can be easily determined. But as can be seen from Fig.2.5 as the biaxial moments increase on the particular section, the axial load capacity Pu of the section goes on decreasing and consequently the ordinate $1/P_u$ goes on increasing. This results in a uniformly expanding failure surface at low axial loads and approximation of a point ($1/P_u$, e_x, e_y) on the failure surface by the equation for Pu is of limited applicability and can be used to check the adequacy of those sections in which compression controls the design. Bresler found that ultimate load predicted by equation (2.4.1) gives maximum deviation of 9% from exact theoretical analysis (Park and Paulay, 1975). This expression has been adopted by Russian Code of practice.

2.4.3 Load Contour Method - Bresler's Approach

In another approach Bresler (1960) has taken the failure surface S_2 (P_u, M_{ux}, M_{uy}) as shown in Fig.2.6 to arrive at rationale for the analysis and design of reinforced concrete columns under biaxially eccentric loads. Bresler has proposed that when a plane of constant axial load i.e., P_u = Constant, intersects the failure surface S_2, a load contour is obtained, the expression of which is given as follows,

$$\left[\frac{M_{ux}}{M_{uxo}}\right]^{\alpha} + \left[\frac{M_{uy}}{M_{uyo}}\right]^{\alpha} = 1.0$$

Bresler, based on his investigations has suggested that the values of exponent α depends on various factors such as aspect ratio D/b, effective corver ratio d/D, grade of concrete, grade of steel, bar arrangement and largly on the load ratio P_u/P_{uz}.

IS : 456-1978 has considered a single parameter P_u/P_{uz} that govern the value of α. It is given by,

$$\alpha = 1.0 \quad \text{for } P_u/P_{uz} < 0.2$$
$$= 2.0 \quad \text{for } P_u/P_{uz} > 0.8$$

It varies linearly from 1.0 to 2.0 for the value of P_u/P_{uz} varying from 0.2 to 0.8 Variation of α with P_u/P_{uz} is shown in Fig.2.7 Fig.2.8 shows a series of load contours for various values values of the exponent α.

This method has been found to be most suitable in terms of simplicity of form, development of design aids and accuracy. Mehod also has been adopted by Britiesh Code CP110 : 1972.

2.4.4 Load Contour Method - parme's Approach

This approach due to Parme, et al (1966), also known as PCA load contour approach is an extension of the Bresler's load contour approach. It utilizes the failure surface S3 in non dimensional form (P_u/P_{uz} M_{ux}/M_{uzo} M_{uy}/M_{yuo}) as shown in Fig.2.9. Equation of the load contour may be written as,

$$\left[\frac{M_{ux}}{M_{uxo}}\right]^{\ln 0.5/\ln\beta} + \left[\frac{M_{uy}}{M_{uyo}}\right]^{\ln 0.5/\ln\beta} = 1.0$$

Fig.2.9 shows graphical representation of the equation for various values of b. This mehtod has been adopted by AC1318:83 for the analysis and design of rectangular columns. Analysis by Parme et al. indicates that the value of b depends upon many factors such as aspect ration D/b, reinforcement index (w = fy Ast/fc'Db), bar arrangement, grade of concrete, grade of steel and to the larger extent on P_u/P_{uz} . Variation of b with these factors is shown in Fig.2.10 (Wang & Salmon, 1985).

2.4.5 Load Contour Method - Meek's Approximation

PCA load contour method has further synthesized the Meek's bilinear approximation (1963) of the load contour, which yields convenient expressions for the determination of the determination of the design uniaxial moment capacities Muxo or Muyo of a rectangular section under the given biaxial moments M_{ux} and M_{uy} at P_u/P_{uz} = constant. These uniaxial moment capacities have been used for design purposes and an analysis of such design examples based on basic assumptions of combined axial load and bending moment indicaes that the sections are 10 to 15% on conservative side. This is basically due to the fact that a point (M_{ux} / M_{uy}) actually lying on the load contour is assumed to lie on the straight line joining B (β,β) and A (M_{uxo} , 0) or B (β,β) and C (0 , M_{uyo}) as shown in Fig.2.12.

For design purposes, the ratio D/b or b/D is assumed and β = 0.65 is taken for lightly loaded columns. After calculating uniaxial moments M_{uxo} or M_{uyo} section is designed(P_u / M_{uxo}) or (P_u / M_{uy}) whichever may produce critical conditions.

2.5 METHOD EMPLOYED FOR PRESENT WORK

Present work is based on limit state of design of concret. Assumption made for the work in as follows.

2.5.1 Assumptions

All assumptions of IS456 for limit state of collapse : compressions are valid.

(i) Plane sections normal to the axis remain plane after bending.

(ii) The maximum compressive strain in concrete in axial compression is taken as 0.002.

(iii) The maximum compressive strain at the highly compressed extreme fibre in concrete subjected to axial compression and bending and when there is no tension on section shall be 0.0035 minus 0.75 times the strain at the least compressed extreme fiftre. (Fig-2.13)

(iv) The stresses in the reinforcement are derived from representation stress-strain curve for the type of steel used. For design purposes the partial safily fector $\gamma_m = 1.15$ shall be applied.

2.5.2 Effective Length Criteria for Design

Is 456 has given two approaches to calculate effective length of member in appendix D of the code. First one in graphical form and takes into account slenderness ratio of connecting beams & columns at joints. Second one, is in tabular form and conditions are little more idealised.

In present work beside idealised method a second method, also in tabular form and is more realistic is taken from BS:8110. Part1 - 1985. The effective height of a column may be different in the two plan directions.

$$l_{eff} = z l$$

where z is given in Table 2.2

2.5.3 Design of Short Axially Loaded Members in Compression

When the minimum eccentricity as per code does not exceed 0.05 times the lateral dimension, the members may be designed by the following equation:

$$P_u = 0.4 f_{ck} \cdot A_c + 0.67 f_y \cdot A_{sc}$$

P_u = Axial load on the member

f_{ck} = Characteristic compressive strength of the concrete

A_c = Area of Concrete

f_y = Characteristic strength of the compression reinforcement

A_{sc} = Area of longitudinal reinforcement for columns

2.5.4 Design of Members Subjected to Combined Axial Load and Uniaxial Bending

The design procedure that is being followed for members subjected to combined axial load and uniaxial bending is with the help of interaction diagram. The limitations of the interaction diagram plotted do not restrict it utility as quick design tool. While I say limitations, I mean that although different charts (which will be more accurate) is not available for different grade of concrete in SP16.

2.5.5 Design of Members Subjected to Combined Axial Load and Biaxial Bending

The resistance of a member subjected to axial force as to satisty equlibrium of loads and biaxial bending shall be obtained on the basis of asumptions 2.5.4 with neutral axis so chosen and moments about two axes. Alternatively, code suggests single equation which must be satisfied.

$$\left[\frac{Mux}{Mux1}\right]^{\alpha_n} + \left[\frac{Muy}{Muy1}\right]^{\alpha_n} < 1.0$$

Mux, Muy = Moments about X & Y axes due to design loads.

Mux1, Muy1 = Maximum uniaxial moment capacity for an axial load of P_u, bending about X and Y axis respectively and

α_n = Function of (P_u / P_{uz})

P_{uz} = $0.45\ f_{ck} A_c + 0.75\ f_y A_{sc}$

$$\alpha_n = 1 + \frac{P_u / P_{uz} - 0.2}{0.8 - 0.2} \quad \text{for } 0.2 \le P_u / P_{uz} \le 0.8$$

$$\alpha_n = 1 \quad \text{for } \frac{P_u}{P_{uz}} < 0.2$$

$$\alpha_n = 2 \quad \text{for } \frac{P_u}{P_{uz}} > 0.8$$

In the software, this method is adopted . The interaction diagram for bars on all the four sides is made for 20 bars equally distributed on all faces. However, the code suggests that these charts can be of good use if member of bars is greater than 8. For circular sections minimum number of bars should not be less than 6.

2.5.6 Design of Slender Compression Members

The code states, the design of slender compression members shall be based on the forces and the moment determined from an analysis of the structure, including the effect of deflections on moment and forces. When the effect of deflections are not taken into account in the analysis, additional moment given in 2.5.6 shall be taken into acocount in the appropriate direction.

The additional moments Max and May shall be calculated by the following formulae :

$$M_{ax} = \frac{P_u D}{2000} \left\{ \frac{l_{ex}}{D} \right\}^2$$

$$M_{ay} = \frac{P_u b}{2000} \left\{ \frac{l_{ey}}{b} \right\}^2$$

P_u = Axial load on the member

l_{ex} = Effective length in respect of major or axis.

l_{ey} = Effective length in respect minor axis

D = Depth of the cross section at right angles to the major axis and

b = Width of the member

In the case of a braced column without any transverse loads occuring in its height the additional moment shall be added to an intial moment equal to sum of 0.4 M_{u1} and 0.6 M_{u2} where M_{u2} is the larger and moment and M_{u1} is the smaller end moment assumed negative if the column is bent in double curvature. In no case shall the addtionall moment be less than 0.4 M_{u2} nor the total moment including the intial moment be less thean M_{u2}. For unbraced columns, the additional moment shall be added to the end moments.

$$M_{intial} = 0.6\,M_{u2} + 0.4\,M_{u1} \qquad \text{[Single curvature braced]}$$

$$M_{intial} = 0.6\,M_{u2} - 0.4\,M_{u1} \qquad \text{[Double curvature]}$$

$$M_{intial} \nless 0.4\,M_{u2}$$

$$M_{total} = M_a + M_{intial} \nless M_{u2}$$

The additional moment from equation of 2.5.6 are on uneconomical side. A multiplying factor

$$K = \frac{P_{uz} - P_u}{P_{uz} - P_b} \leq 1$$

is used to make it economical

where,

P_u = Axial load on Compression member

p_{uz} = As defined in 2.5.5

P_b = Axial load corresponding to the condition of maximum compressive strain of 0.0035 in cocrete and tensile strain of 0.002 in outer most layer of ten sion steel.

2.5.7 Design of Lateral ties

The diameter of polygonal links or lateral ties should not be less than one-fourth of the diameter of the largest longitudinal bar and in no case less than 5 mm.

The pitch of the lateral ties should not exceed the following distances :

(i) The least lateral dimension of the compression member.

(ii) Sixteen times the smallest diameter of the longitudinal reinforcement bar to be tied, and

(iii) Forty eight times the diameter of lateral ties.

2.5.8 Design of Helical Reinforcement

(i) The diameter of the helical reinforcemant should not be less than one fourth of the diameter of the largest longitudinal bar and in no case less than 5 mm.

(ii) Helical reinforcement should be of regular formation with turn of helix spaced evenly and its end should be anchored properly by providing one and half extra turns of the spiral bar.

(iii) If an increased load on the column on the strength of the helical reinforcement is allowed for, its pitch should not exceed the following distances :

a) 75 mm

b) One-sixth of the core diameter of the column.

The pitch should not be less than the following distances :

a) 25 mm

b) Three times the diameter of the steel has forming the helix.

(iv) If an increased load on the strength of helix reinforcement is not allowed for, its pitch should not exceed the following distances :

a) The least lateral dimansion of the compression member.

b) Sixteen times the smallest diameter of the longitudinal bar to be tied and

c) Forthy-eight times the diameter of the helical bars.

2.6 PREVIOUS WORK

2.6.1 Work at University of Roorkee

Many works have already taken on design of R.C.C. columns. In this section a review of different works have been done. It also signify why there in another package on design of R.C.C. columns is necessary.

Pandey (1989), has done exhaustive work with different analysis methods for biaxial bending. It suggests even methods of analysis for T section, I sections etc. However, only cases of short column have been considered. It provides programmes in iterative approach based on assumption of neutral axis for retangular uniaxial & biaxial cases only. It does not takes into account the braced cases.

Sharma (1994), He also adopted the same procedure as above in his work.

Tripati (1995), has designed uniaxial columns using same algorithms.

Gupta (1997), have provided package for design of R.C.C. short columns. This work includes analysis of rectangular columns in uniaxial as well as biaxial case using the working stress approach Analysis and design of retangular columns in biaxial bending at ultimate load have also been studied.

Ansari (1997), has also programmed for design of rectangular columns in axial bending & uniaxial bending cases.

2.6.2 Work at Central Building Research Institute

COLUMN package has been developed for design and drafting of short rectangular columns with axial load and uniaxial bending. The package developed in FORTRAN 77 and using 17 PGL language for drafting. The design of Column is based on the limit state method as per IS : 456. The drawing of the cross section and longitudinal section of column gives details of main and transverse reinforcement.

2.7 EDGE OF PRESENT WORK OVER PREVIOUS WORK

(i) It is a well known fact that SP:16 charts provides a less dedious task for user. It is first time, that these charts as being included in program in as it is form.

(ii) This package considers rectangular as well as circular sections under axial compressive load & different combination of moments.

(iii) Present work facilitates of the braced column case too.

(iv) It facilitates the use of helical reinforcement.

(v) Effect of slenderness ratio is taken into account.

All these features give this package an edge over the previous work undertaken and makes if even commercially attractive.

3. FEATURES OF PROGRAM

3.1 Programming Language

For this particular work programming language used is C. C provides facilities to deal with string, mathematics, input, output etc and other regular features with user friendly syntax. Moreover, it facilitates low level programming, interaction with the operating system and hardware through the program itself. This makes C a superior language than FORTRAN. A remarkable aspect of this language is its extensibility i.e. new features and functions can be added in its compiler itself. Any nice function can be made a part of the compiler. It has emerged as a language of choice for most applications due to speed, portability and compactness of code. It has now been implemented on virtually every sort of computer, from micro to mainframe. Intially, the facto standard for implementing the language has been the original C reference manual by Kernighan and Ritchie published in 1978. Gradually, it grew and many changes took place. This has resulted in minor problems in terms of portability of programs. Consequently, the American National Standard Institute (ANSI) constituted a committee to go into the language features and to produce a more comprehensive and unambiguous definition of C. The result is ANSI C. Most compilers have already adopted ANSI standards.

C language is well suited for structured programming, thus requiring the user to think problems in terms of function modules or blocks. This modular structure makes program debugging, testing and maintenance easier.

3.2 C Compilers for Microcomputers

Now a days C compilers for P.C comes as a subset of corresponding C++ compiler. TurboC++, Boroland C++, Quick C++, Microsoft C++, Microsoft Visual C++, Power C++ are few popular compilers for personal computer users. For this project work Turbo C++ 1.5 is being used. It provides many header files over ANSI standard, Like Graphics.h, Conio.h, Dos.h, Process.h etc. TCC C (turbo C) compiler provides graphics user interface to the programmer. Help is available for various commands and function on mouse button press.

3.3 Hardware Platform of Programming

The project was completed on pentium 100 Hz. Cpu memory of the aforesaid computer was 16 MB and harddisk space 1.2 GB. Highest graphics adaptar was VGA. VGA in its highest mode facilated 650 x 450 pixels.

3.4 Hardware Requirement to Run This Software

This software will work on all dos & windows environment. However, a computer having graphics adapter will be preferred to provide the right aesthetics. Graphics adapter less than 650 x 450 resolution may cut some part of SP16 charts on monitor.

3.5 ORGANIZATION OF SOFTWARE

A block diagram is drawn to show control as well as data transfer between the variour program. It is worthwhile to get these information before we know what are they doing. The attributers on the control transfer gives sequence of control transfer as shown in Fig 3.1.

There is no equivatent control transfer between COLAXIAL ( ) & draw.exe as equivatent to 4 & 5. Controls 6-7, 6'-7', 6"-7" are competetive and only one can occur for a particular program.

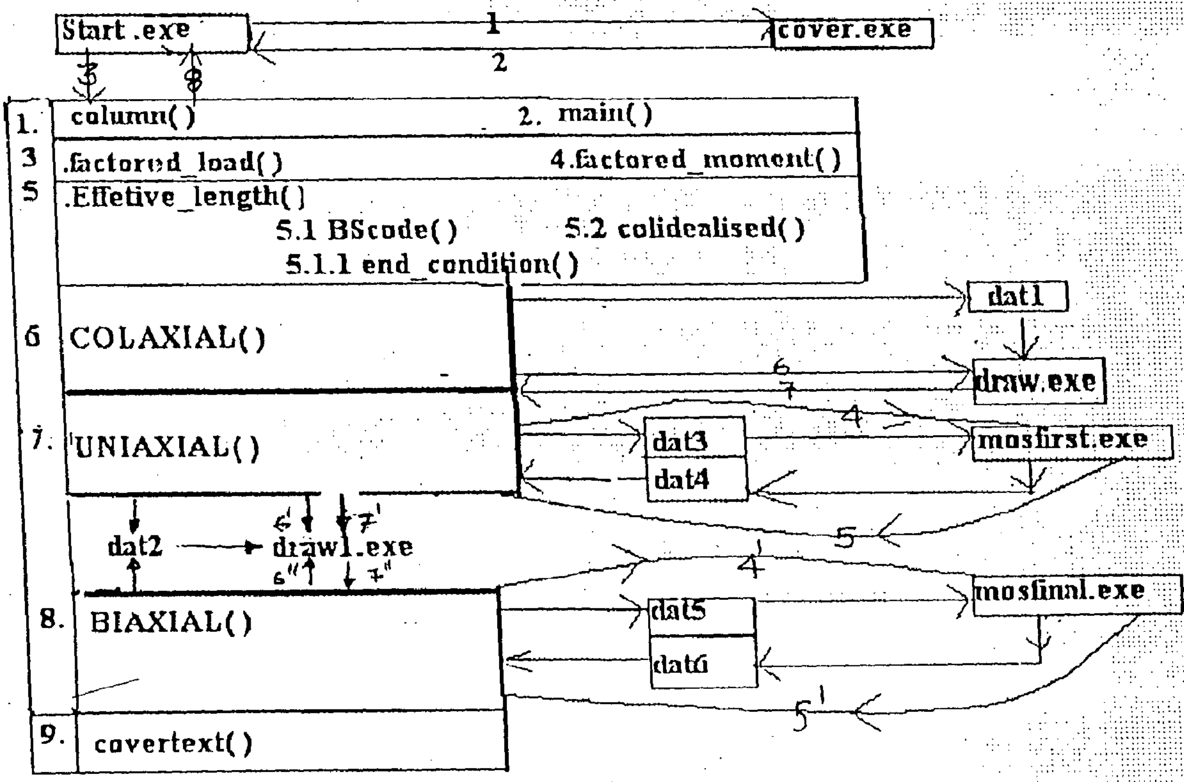


Fig.3.1 SEQUENCE OF CONTROL TRANSFER

3.6 Flow Chart & Discussions

Flow charts are very useful tool to visualize logic of a particular program Flows charts of different parts of the software concerned having important steps, are listed at the end.

3.6.1 Start.C

It is the master program which runs cover.C first and then major.C afterwards. It doesn't require much explanation.

3.6.2 Cover.C

It takes control from start.C. It displays "DESIGN OF R.C.C.COLUMN" in 5 different fonts in horizontal as well as vertical direction. Then transfer backs the control to start C.

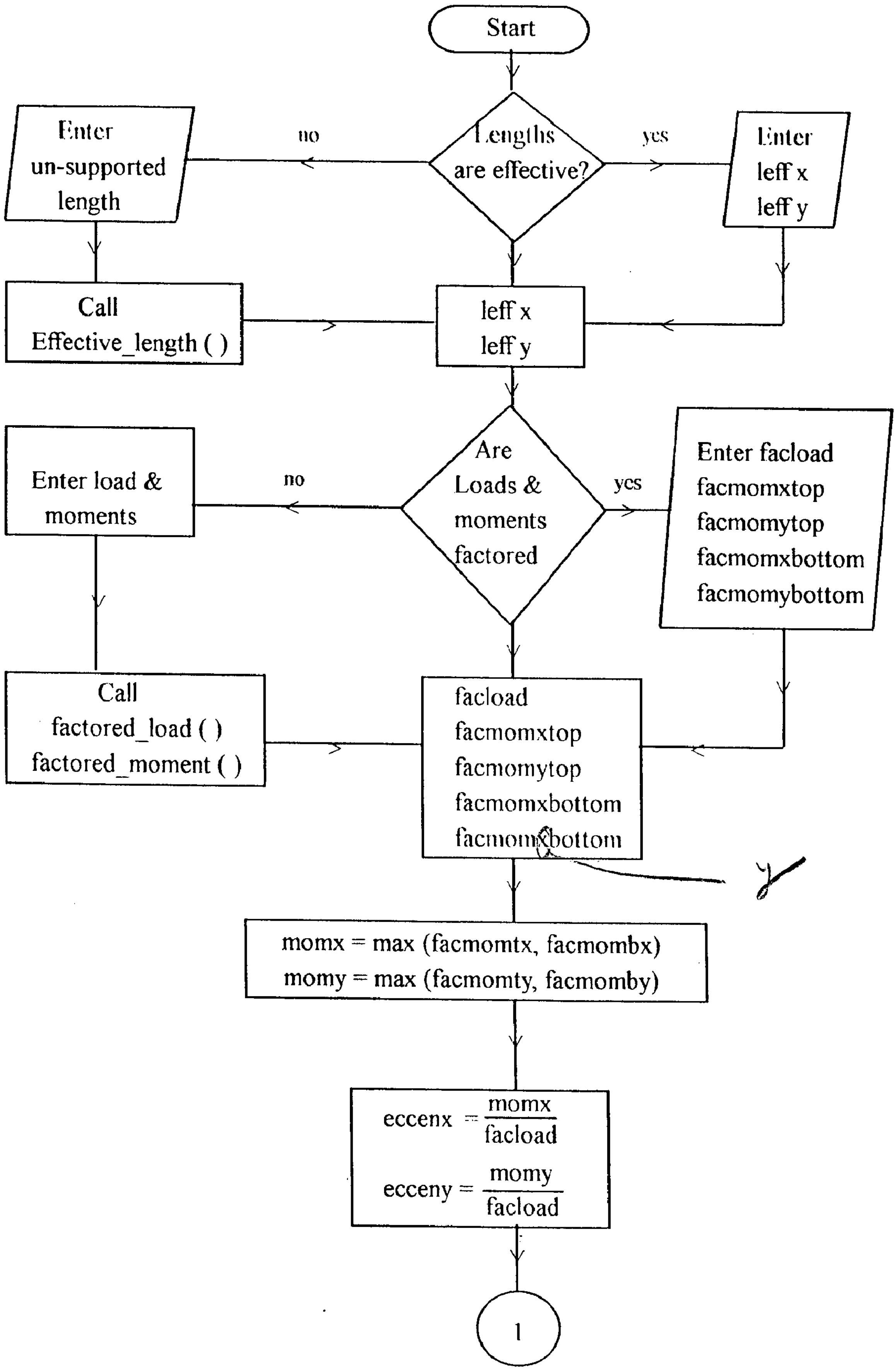
3.6.3 Major.C

Since it contains a lot of functions and lines of program is around 1800. It is better to consider different functions separately.

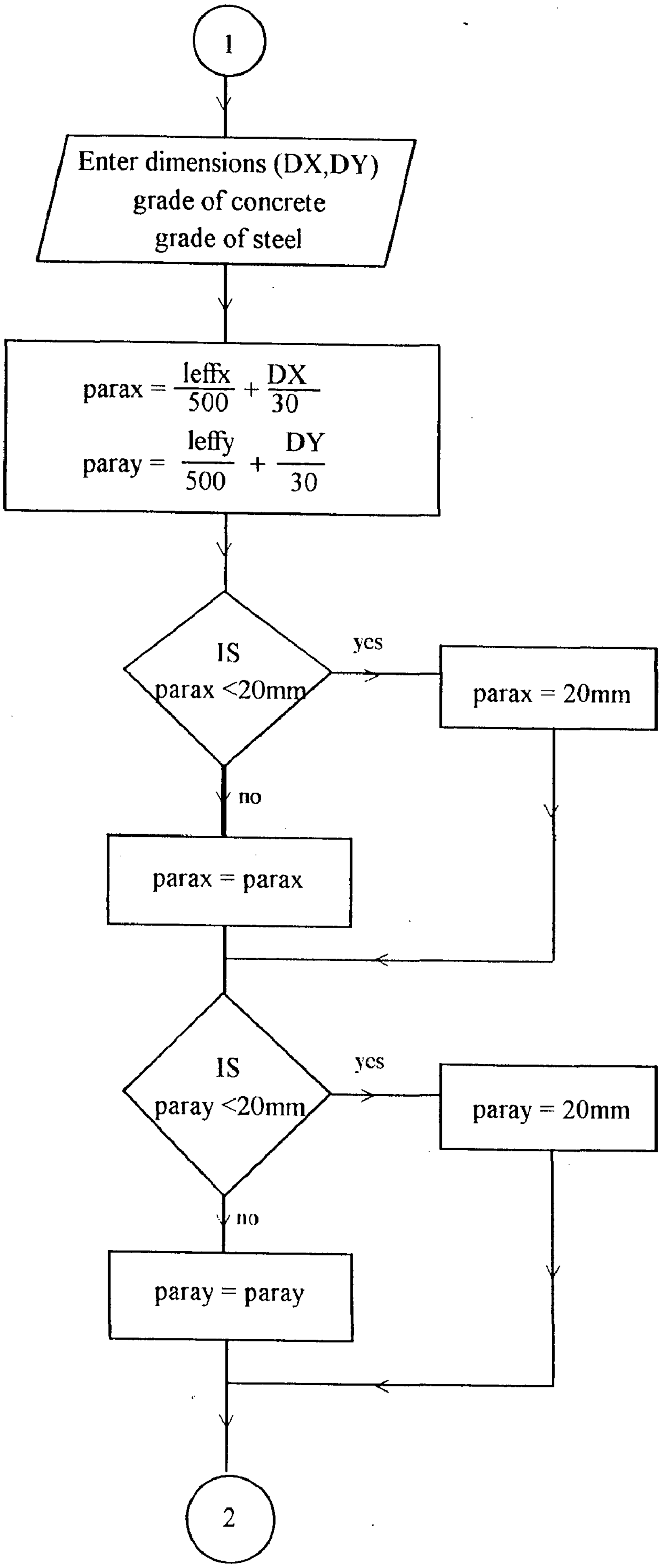
The main ( ) function of major C decides whether the case is axial, uniaxial or biaxial. The detailed flowchart is being given in Figure.3.2.

3.6.3.1 Main ( )

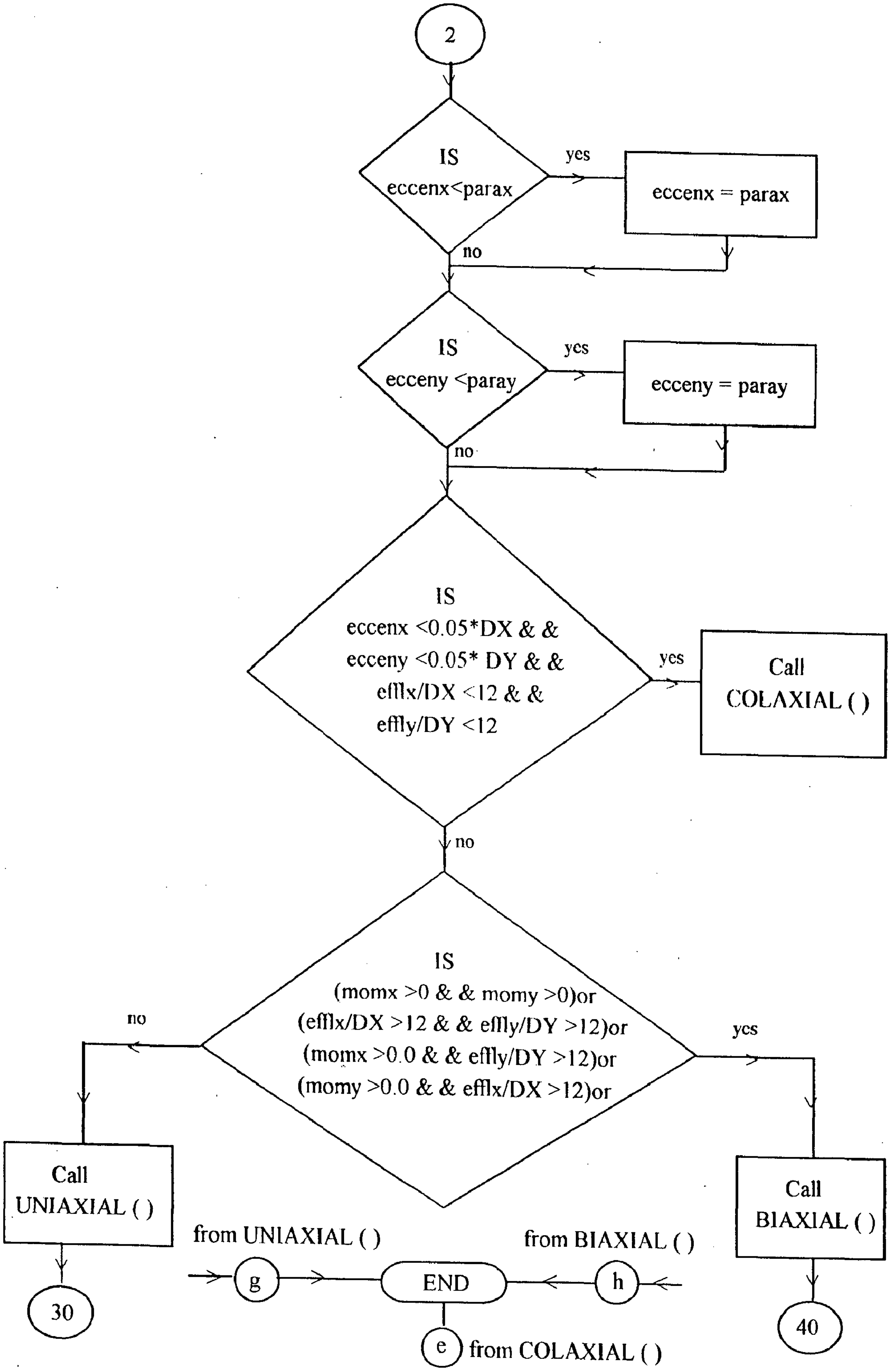
Fig.3.2 Flow chart of main ( )



Continue


1
Enter dimensions (DX,DY)
grade of concrete
grade of steel
parax = leffx/500 + DX/30
paray = leffy/500 + DY/30
IS
parax <20mm
yes
parax = 20mm
no
parax = parax
IS
paray <20mm
yes
paray = 20mm
no
paray = paray
2

Continue


2
IS
eccenx<parax
yes
eccenx = parax
no
IS
ecceny <paray
yes
ecceny = paray
no
IS
eccenx <0.05*DX & &
ecceny <0.05* DY & &
efflx/DX <12 & &
effly/DY <12
yes
Call
COLAXIAL ( )
no
IS
(momx >0 & & momy >0)or
(efflx/DX >12 & & effly/DY >12)or
(momx >0.0 & & effly/DY >12)or
(momy >0.0 & & efflx/DX >12)or
no
yes
Call
UNIAXIAL ( )
Call
BIAXIAL ( )
from UNIAXIAL ( )
from BIAXIAL ( )
g
END
h
30
40
e
from COLAXIAL ( )

3.6.3.2 Column ( )

This function is accessible to each and every function of major. c. Each time when this function is called clears the screen, writes `column' vertically at right side of screen.

3.6.3.3 Effetive_Length ( )

When it is called it asks wheather one want to use BS Code ( ) method or colidealised ( ) of IS456 to calculate effective length. It returns effective length to main ( ).

3.6.3.3.1 BS_Code ( )

It displays options by calling endcondition ( ). Subsequently it calculate effective_length and return it to Effective_length ( ).

3.6.3.3.1.1 End_Condition ( )

When it is called by BS Code ( ), displays possible end conditions & then return control to BS Code ( ).

3.6.3.2 Colidealised ( )

It takes control from Effective_length ( ), calculates effective_length and return it to Effective_length ( ).

3.6.3.4 Factored_Load ( )

It takes control from main, calculates factored_load and then return it to main ( ).

3.6.3.5 Factored_moment ( )

It do similar treatment with moments as factored_load do with loads.

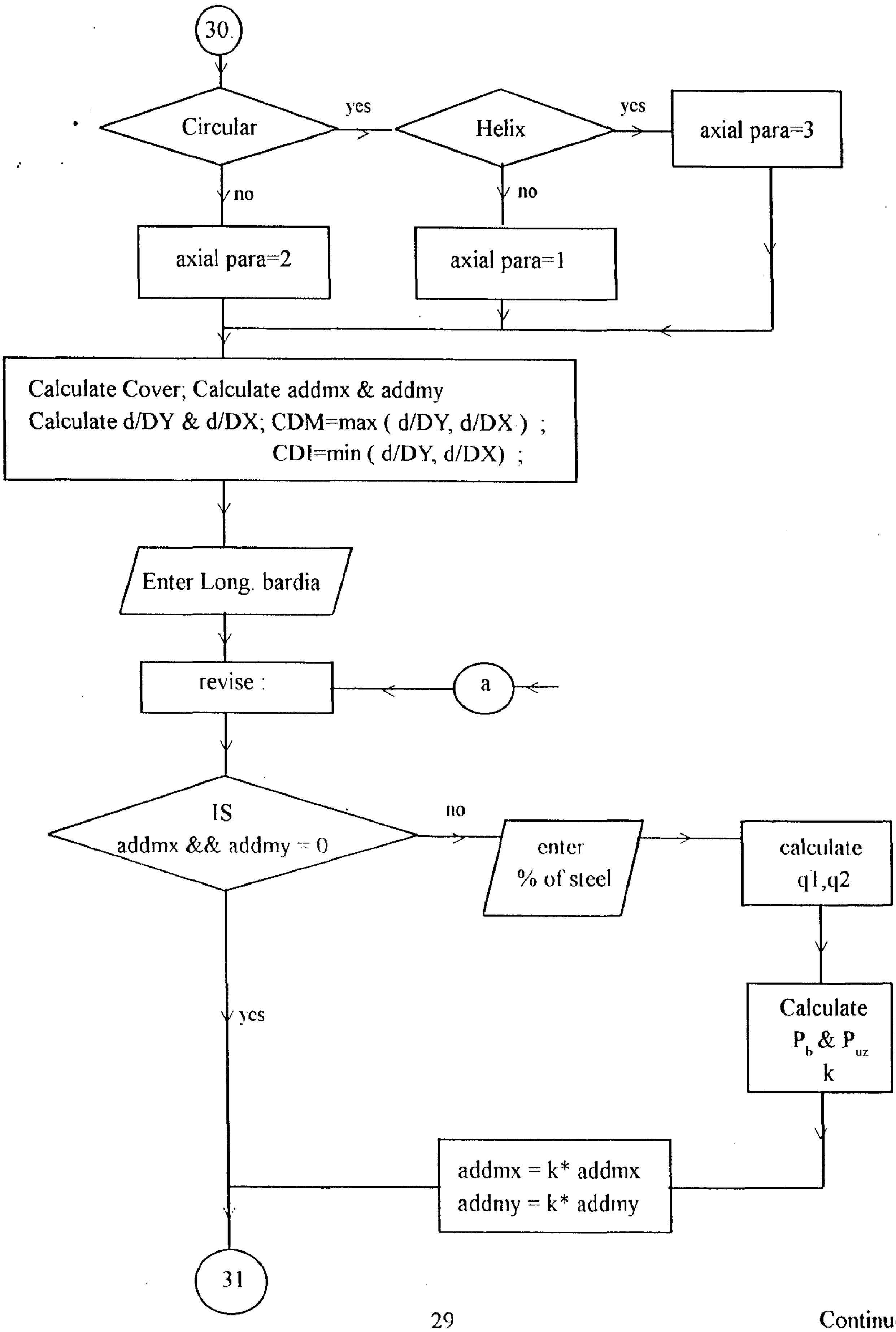
3.6.3.6 COLAXIAL ( )

This function designs columns (rectangular as well as circular) for axial case. It satisfies provisions for reinforcemoment (included helix), cover, diameter of main an well as lateral bars, pitch and all such conditions as demanded by IS:456. Finally, it drafts cross-section of the column.

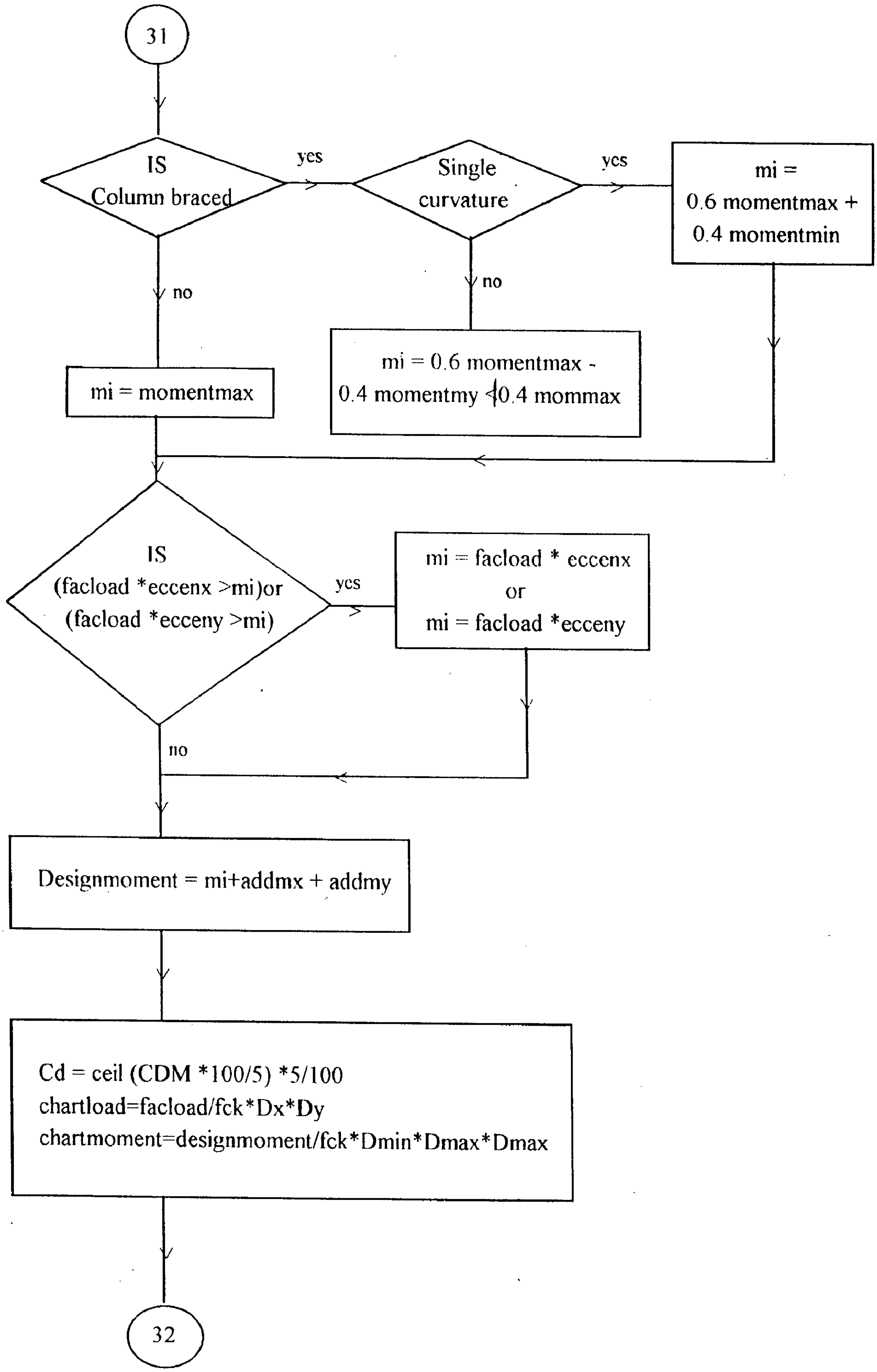
3.6.3.7 UNIAXIAL ( )

It provides all facilities as given in 3.6.6 In addition to these facilities. It considers the different provisions of slenderness ratio and encorporates it into the program. Program facilates conditions when columns are being braced and deflected in single curvature as well as double curvature. The major part of process in form of defailed flow chart is given in Fig.3.3.

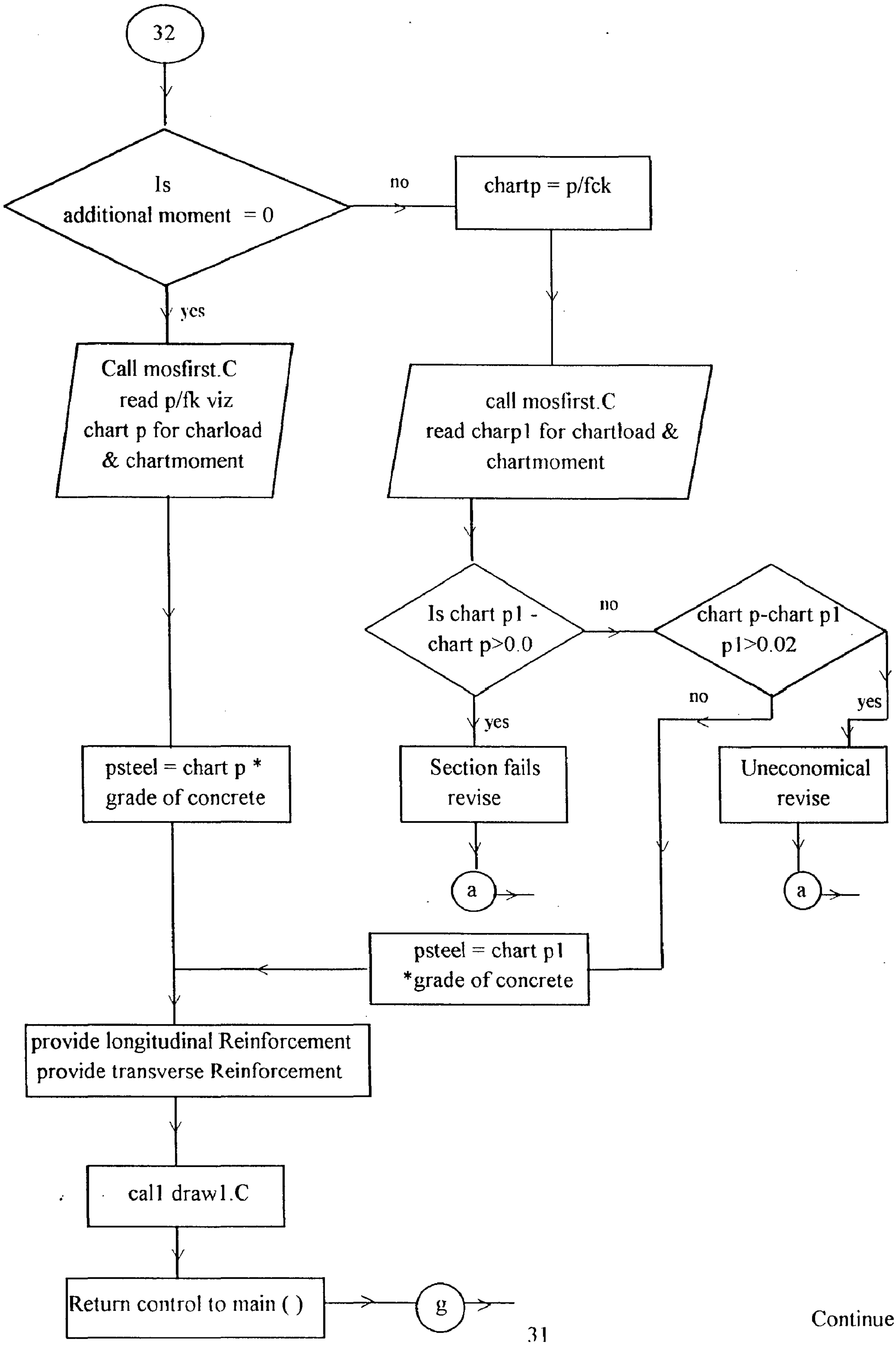
Fig.3.3 Flowchart of UNIAXIAL ( )



Continue


31
IS
Column braced
yes
Single
curvature
yes
mi =
0.6 momentmax +
0.4 momentmin
no
no
mi = momentmax
mi = 0.6 momentmax -
0.4 momentmy <0.4 mommax
IS
(facload *eccenx >mi)or
(facload *ecceny >mi)
yes
mi = facload * eccenx
or
mi = facload *ecceny
no
Designmoment = mi+addmx + addmy
Cd = ceil (CDM *100/5) *5/100
chartload=facload/fck*Dx*Dy
chartmoment=designmoment/fck*Dmin*Dmax*Dmax
32

Continue


32
Is
additional moment = 0
no
chartp = p/fck
yes
Call mosfirst.C
read p/fk viz
chart p for charload
& chartmoment
call mosfirst.C
read charp1 for chartload &
chartmoment
Is chart p1 -
chart p>0.0
no
chart p-chart p1
p1>0.02
no
yes
yes
psteel = chart p *
grade of concrete
Section fails
revise
Uneconomical
revise
a
a
psteel = chart p1
*grade of concrete
provide longitudinal Reinforcement
provide transverse Reinforcement
call draw1.C
Return control to main ( )
g

Continue

3.6.3.8 BIAXIAL ( )

It provides all code facilities as described in 3.6.3.6 for cover etc for biaxial case. The process used in this function is iterative in nature. For each trial a condition as described in code is tested. The process scheme for the function with detailed flow chart is given in Fig.3.4.

3.6.3.9 Covertext ( )

This function is text of conditions regarding cover. Its accessible to COLAXIAL ( ), UNIAXIAL ( ), BIAXIAL ( ).

3.6.4 Mosfirst.C

It's new concept as far as dissertations are concerned. This program facilates use of mouse for getting data from SP-16 charts for uniaxial case. All you have to do is to clik the mouse button. This program takes control from UNIAXIAL ( ) function of major.c & returns control to the same.

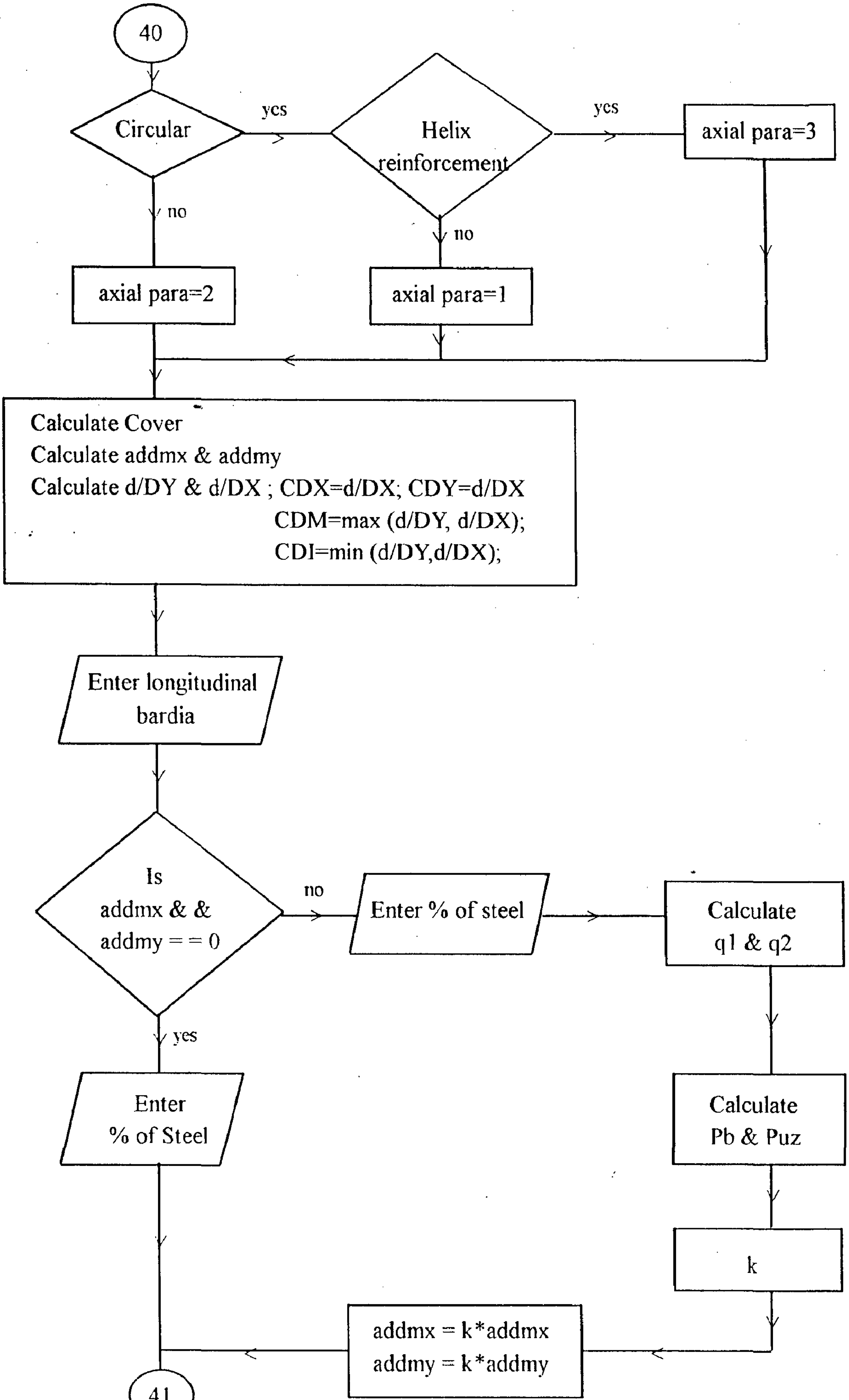
3.6.5 Mosfinal.C

It does the same thing for BIAXIAL ( ) what mosfirst.C do for UNIAXIAL ( ). It takes control from BIAXIAL ( ) return control to the same.

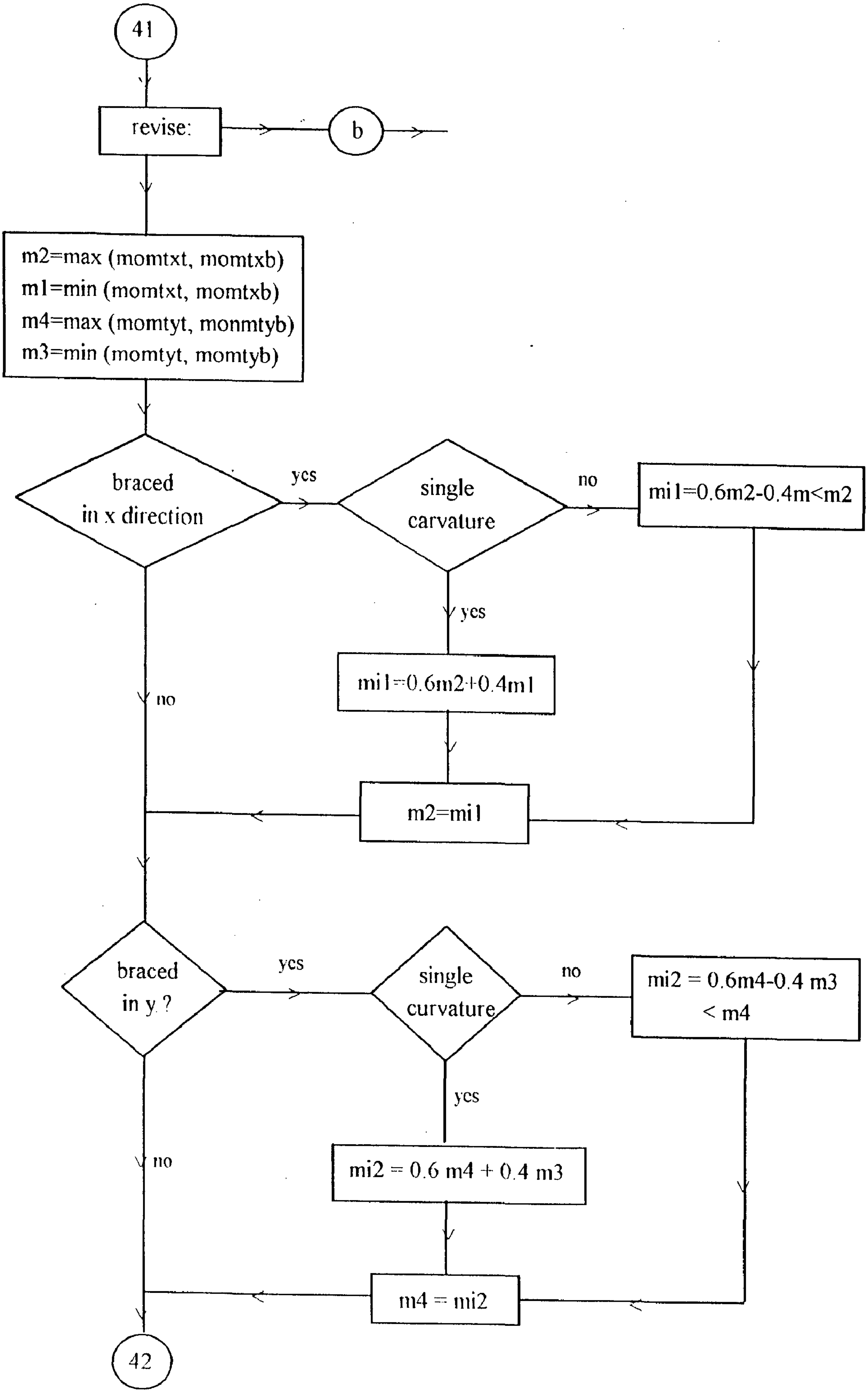
3.6.6 Draw.C

Drafts section for COLAXIAL ( ) case.

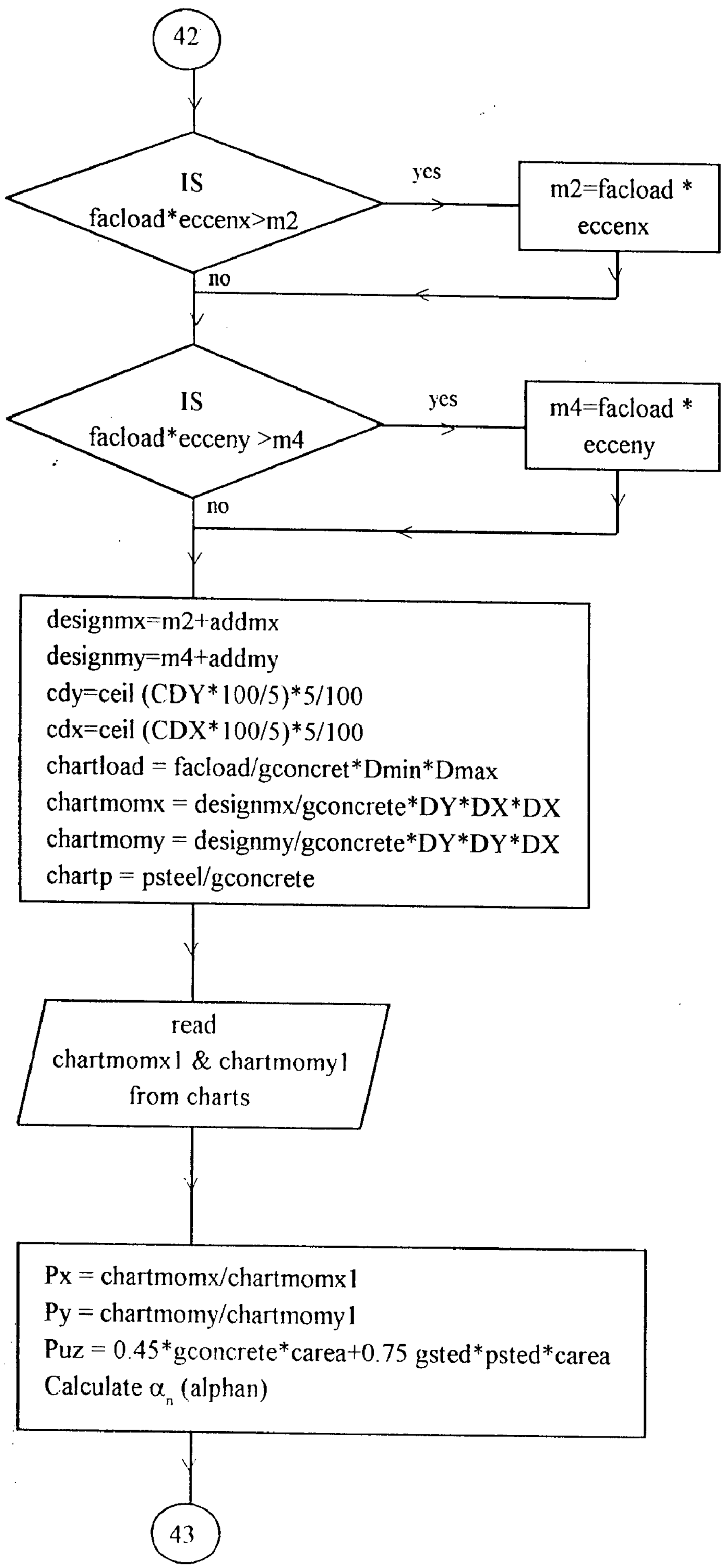
Fig.3.4. Flow Chart of BIAXIAL ( )



Continue

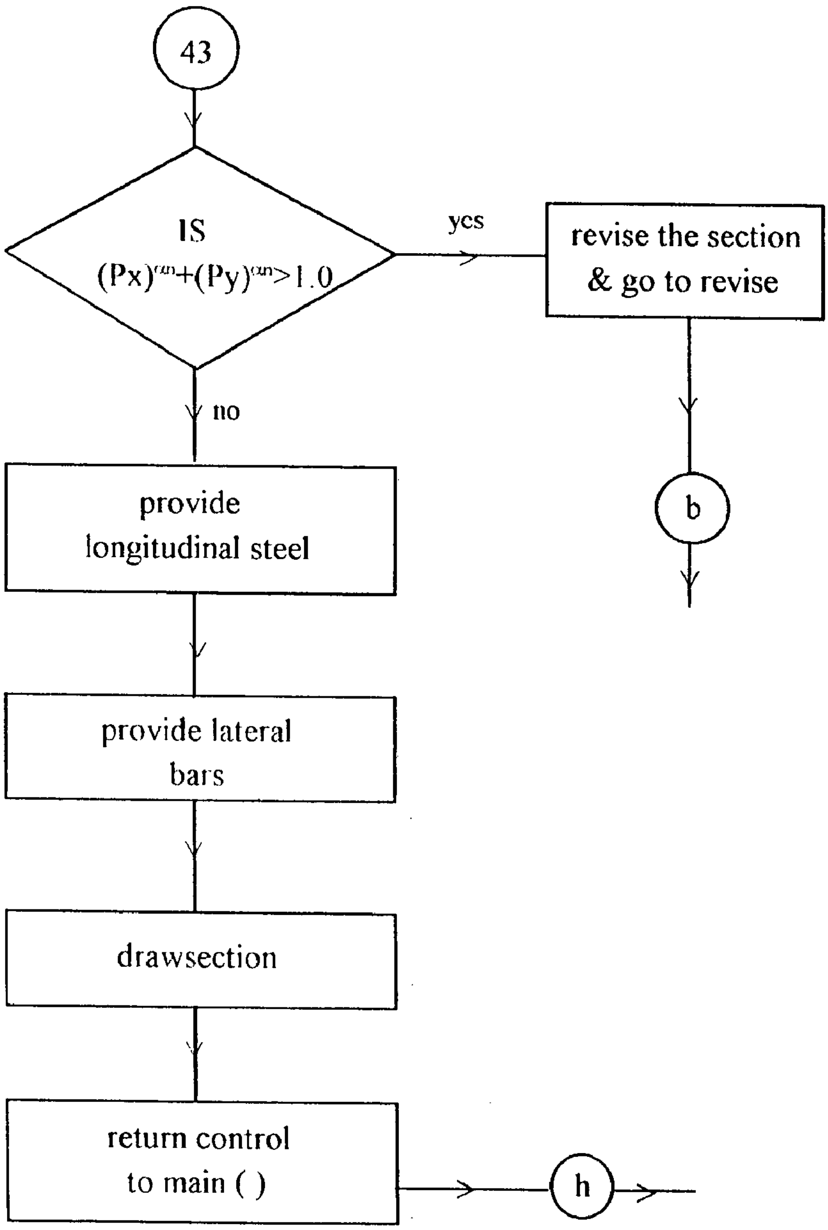

41
revise:
b
m2=max (momtxt, momtxb)
m1=min (momtxt, momtxb)
m4=max (momtyt, monmtyb)
m3=min (momtyt, momtyb)
braced
in x direction
yes
single
carvature
no
mi1=0.6m2-0.4m<m2
yes
mi1=0.6m2+0.4m1
no
m2=mi1
braced
in y ?
yes
single
curvature
no
mi2 = 0.6m4-0.4 m3
< m4
yes
mi2 = 0.6 m4 + 0.4 m3
no
m4 = mi2
42

Continue



42
IS facload*eccenx>m2
yes
m2=facload * eccenx
no
IS facload*ecceny >m4
yes
m4=facload * ecceny
no
designmx=m2+addmx
designmy=m4+addmy
cdy=ceil (CDY*100/5)*5/100
cdx=ceil (CDX*100/5)*5/100
chartload = facload/gconcret*Dmin*Dmax
chartmomx = designmx/gconcrete*DY*DX*DX
chartmomy = designmy/gconcrete*DY*DY*DX
chartp = psteel/gconcrete
read chartmomx1 & chartmomy1 from charts
Px = chartmomx/chartmomx1
Py = chartmomy/chartmomy1
Puz = 0.45*gconcrete*carea+0.75 gsted*psted*carea
Calculate α_n (alphan)
43

Continue


43
IS
(Px)^αn+(Py)^αn>1.0
yes
revise the section
& go to revise
no
b
provide
longitudinal steel
provide lateral
bars
drawsection
return control
to main ( )
h

3.6.7 Draw1.C

Drafts section for UNIAXIAL ( ) & BIAXIAL ( ) Case.

3.7 Processing time of programme

In an interactive programming repetetive interface of of user is required in between processing of program. Therefore, processing time of programme is a trivial quantity for interactive software. However, for the present software when an example was taken for biaxial bending case of slender and braced column with no iteration case and programme being modified so that all input were given at a time. The processing time was 623 milliseconds. It was done on 100 MHz pentium platform. Time was calculated with the facilities of lowlevel programming of 'C'.

CHAPTER - 4

TYPICAL INPUT AND OUTPUT

Some problems are being selected from solved examples on this topic. Input is being given in program and output is being compared to validate the present work.

1. Axially loaded column solved example of 9.13 of Sinha (1996)

   Design data :

size of column	=	350x350mm
factored axial load	=	1500 kN
concrete grade	=	M25
Steel grade	=	Fe415

   Column is short

Input for above problem

i) Are you revising section Y/N

   Value entered = N

ii) You wish to enter effective length (e/E) or calculate effective length (u/V).

   Value entered = e

iii) Enter effective length in x direction

   value entered = 1

Remarks : Since column is short any dimension less that 12x lateral dimension was entered

iv) Enter effective length in y direction(m)

   value entered = 1

v) Enter unsupported length(m)

   value entered = 1

vi) Enter 1 if load is factored load 2 if it is to be converted.

   Value entered = 1

vii) Enter load in KN

   value entered = 1500

viii) Enter moment in x direction at top and bottom (kNm)

value entered = 0 0

ix) Enter moment in y direction at top and bottom (kNm)

value entered = 0 0

x) Dimension in x DX and in y DY (mm) ?

value entered = 350 350

xi) Enter grade of concrete and steel.

value entered = 25 415

xii) Is it a circular column, y/N,

value entered = N

xiii) Enter dia of longitudinal bar in mm.

value entered = 20 [As used in the book]

Output : Steel area = 1025.93 mm^2

number of bars = 4-20ϕ

area provided = 1257 mm^2

Remarks : Results are same as into solved example.

Example 2 Slender braced circular column under uniaxial bending. Solved example Jain(1995) 16.9.

Design data

size of column	=	40cm
Concrete grade	=	M20
Steel grade	=	Fe415
Effective length	=	6m
Unsupported length	=	7 m
Factored load	=	1200 kN
Factored moment	=	75 kNm at top
	=	50 kNm at bottom

Input for above problem

i) Are you revising your section Y/N.

Value entered = N

ii) You wish to enter effective length (e/E) or calculate effective length (u/U)

value entered = e

iii) Enter effective length in x direction(m)

value entered = 6m

iv) Enter effective length in y direction(m).

value entered = 0

v) Enter unsupproted length (m)

value entered = 7

vi) Enter 1 if load is factored load 2 if it is to be converted

value entered =1.

vii) Enter laod in kN

value entered = 1200 kN.

viii) Enter moment in x direction at top and bottom (kNm)

value entered = 75 50

x) Enter moment in y direction at top and bottom(xNm)

value entered = 0 0.

xi) Dimension in x direction DX and in y DY (mm)?

value entered = 400 400

xii) Enter grade of concrete and steel

value entered = 20 415

xii) Is it a circular column Y/N

value entered = Y.

xii) Do you wish to provide helix reinforcement if yes types H.

Value entered = N.

xiv) Enter dia of longitudial bar (mm)

value entered = 22

xiv) Single curvature or double curvature s/d

value entered =s.

xix) Value read from chart of program corresponding to d/D = 0.15

For chart load = $P_u/f_{ck}\ D^2 = 0.375$

chart moment = $M_u/f_{ck}\ D^3 = 0.0761$

p/f_{ck} comes = 0.1294

$\Rightarrow p = 2.588 < 2.6$

OUTPUT

Steel area = 3267.25 mm^2

Steel area in book = 3265 mm^2

number of bars provided = 10-22ϕ

Remarks

A little variation in results is due to the fact that book has rounded the value.

3. Slender unbraced rectangular column Jain (1995) solved example no 16.10

Design data :

Size of column	=	25cm x 30 cm
Concrete grade	=	M15
Steel grade	=	Fe 250
Effective length lex	=	3m
Effective length ley	=	4m
Unsupporeted length	=	5m
Factored load P_u	=	500 kN

Factored moment in the direction

of larger dimension My = 12 kNm

Factored moment in the direction of shorter dimension Mx = 7.5 kNm

reinforcement on both sides

Input For above Problem

i) Are you revising your section Y/N

value entered = N

ii) Do you wisth to enter effective length (e/E) or calculate effective length (u/U).

value entered = e

iii) Enter effective length in x direction(m)

value entered = 3m

iv) Enter effective length in y direction (m)

value entered = 4m

v) Enter unsupported length(m)

value entered = 5m

vi) Enter 1 if load is factored laod 2 if it is to be converted

value entered = 1.

vii) Enter load in kN

value entered = 500 kN

viii) Enter moment in x direction at top and bottom (kNm)

value entered = 7.5 0

ix) Enter moment in y direction at top and bottom (kNm)

value entered = 12 0

x) Dimention in x DX (mm) and in y DY (mm) ?

Value entered = 250 300

xi) Enter grade of concrete and steel

value entered = 15 250

xii) Enter dia of longitudinal bar (mm)

value entered = 16mm

xiii) Enter trial % of steel

value entered = 2

v) Enter 1 to enter cover 2 for default

value entered = 1

xv) Enter cover in mm

value entered = 40 mm [as in book]

xvi) Is it a braced column Y/N.

Value entered = N

xvii) Value read from chart of program for chart load = P_u/f_{ck} DX* Dy = 0.444

chartp = p/f_{ck} = 2/15 = 0.133

In x direction chart for d'/D = 0.20 was used

In y direction chart for d'/D = 0.20 was used

Output

$(chartmomx/chartmomx1)^{\alpha} + (chartmomy/chartmomy1)^{\alpha} = 0.7986 < 1$

Steel area = 1500 mm^2

number of bars provide = 8

Steel area provided = 1608.2 mm^2

Remarks : Results from book and program both satisfy the condition.

CHAPTER -5

CONCLUSIONS AND FURTHER SCOPE OF WORK

5.1 CONCLUSIONS

i) The main objective of present work was to develop a user friendly software for design of RCC columns. The software developed provides facilities of interactive programming.

ii) This work includes all possible cases for design of columns in axial compression and bending. The work includes effect of slenderness and bracing of column in two directions. The present package allows for different load conditions at two ends of columns.

iii) The results of design from present software when compared with solved examples of standard books validated the effort.

5.2 FURTHER SCOPE OF WORK

This software pacakage can be made more exhaustive.

(i) By including mouse all over the program. It will also need menu driven items for most of steps. It will minimize data entry from keyboard. It will enhance its userfriendly nature.

(ii) Inclusion of axial tension with or without bending and

(iii) Better drafting of reinforcement detailing.

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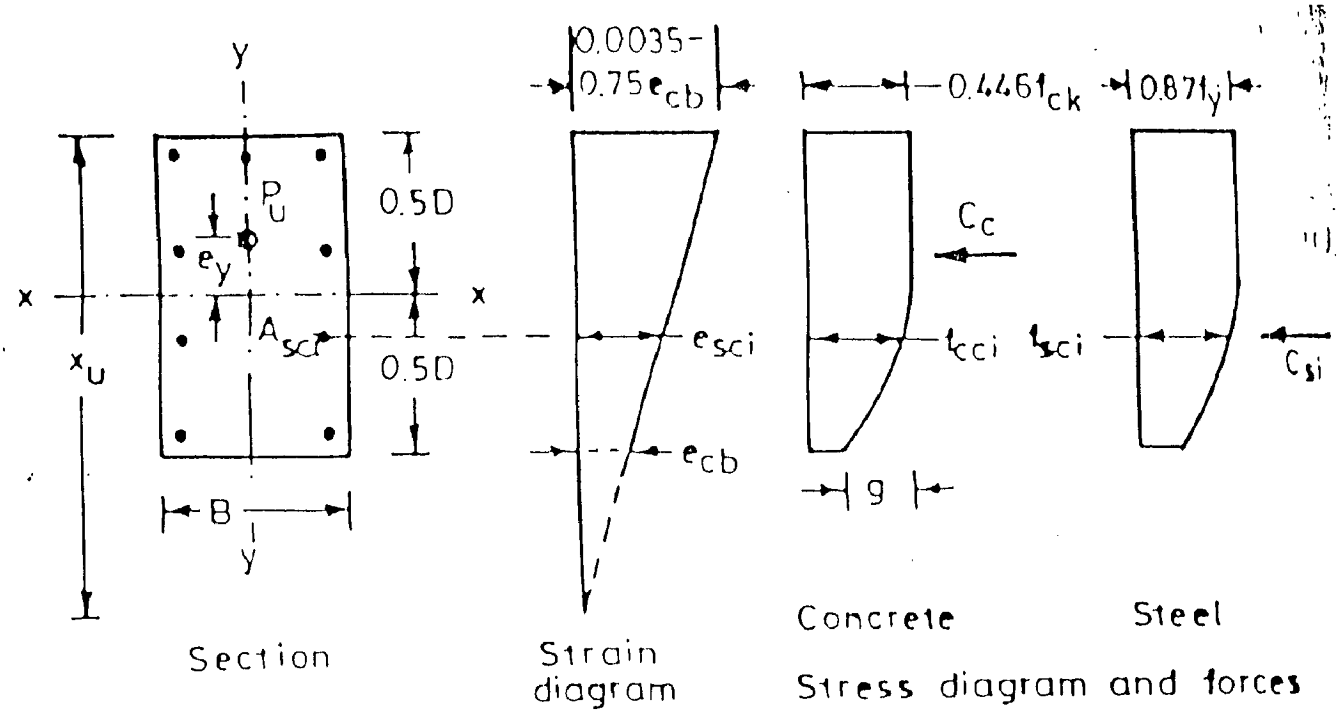


Fig.2.1 NEUTRAL AXIS OUTSIDE THE SECTION

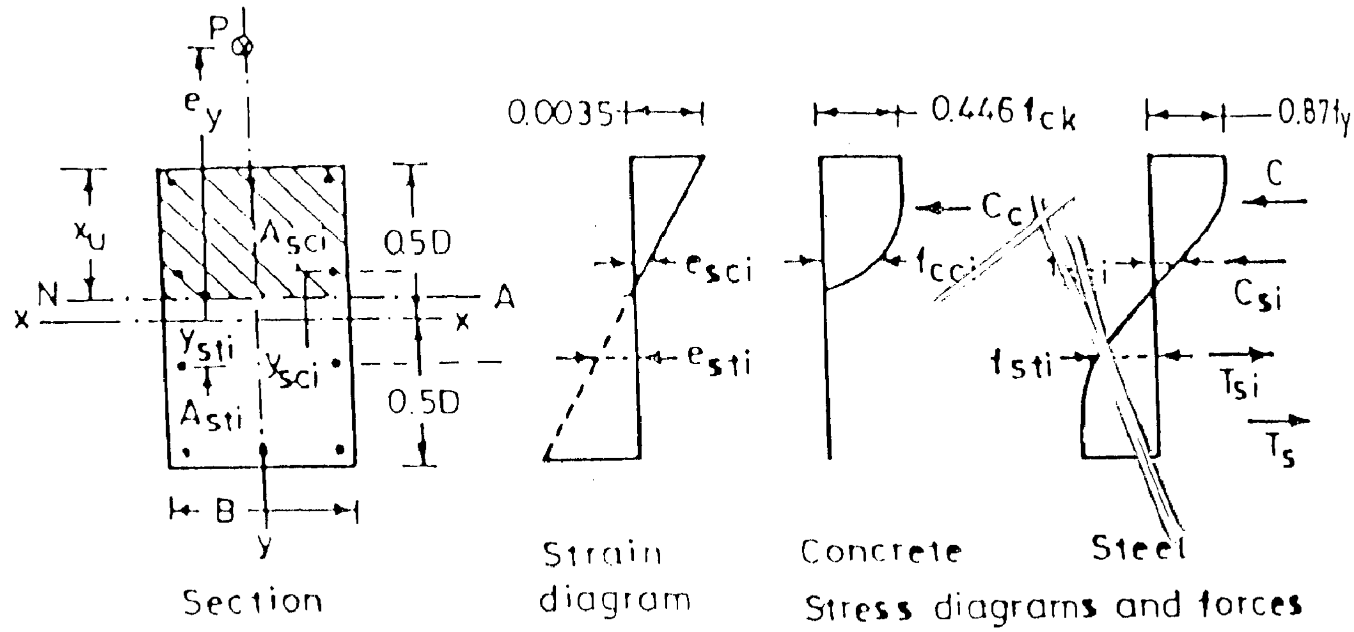


Fig.2.2 NEUTRAL AXIS WITHIN THE SECTION

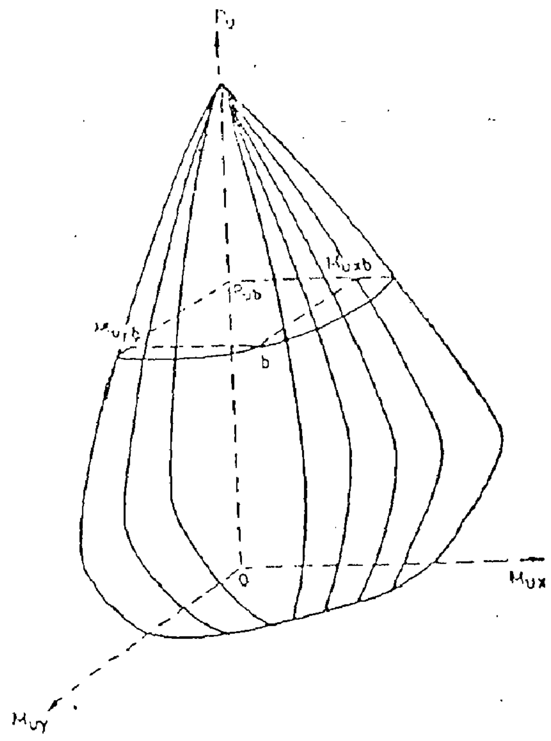


Fig.2.3 P - M_x - M_y INTERACTION SURFACE

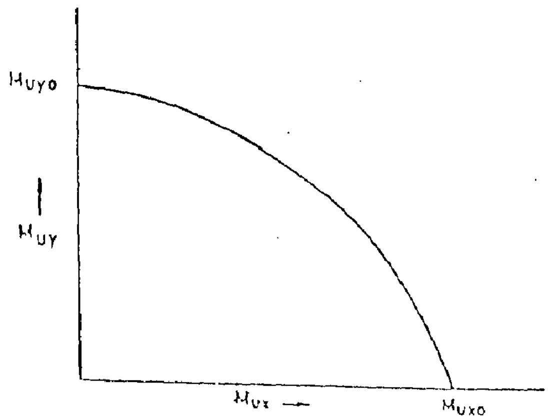


Fig.2.4 BIAXIAL MOMENT INTERACTION CURVE AT CONSTANT LOAD

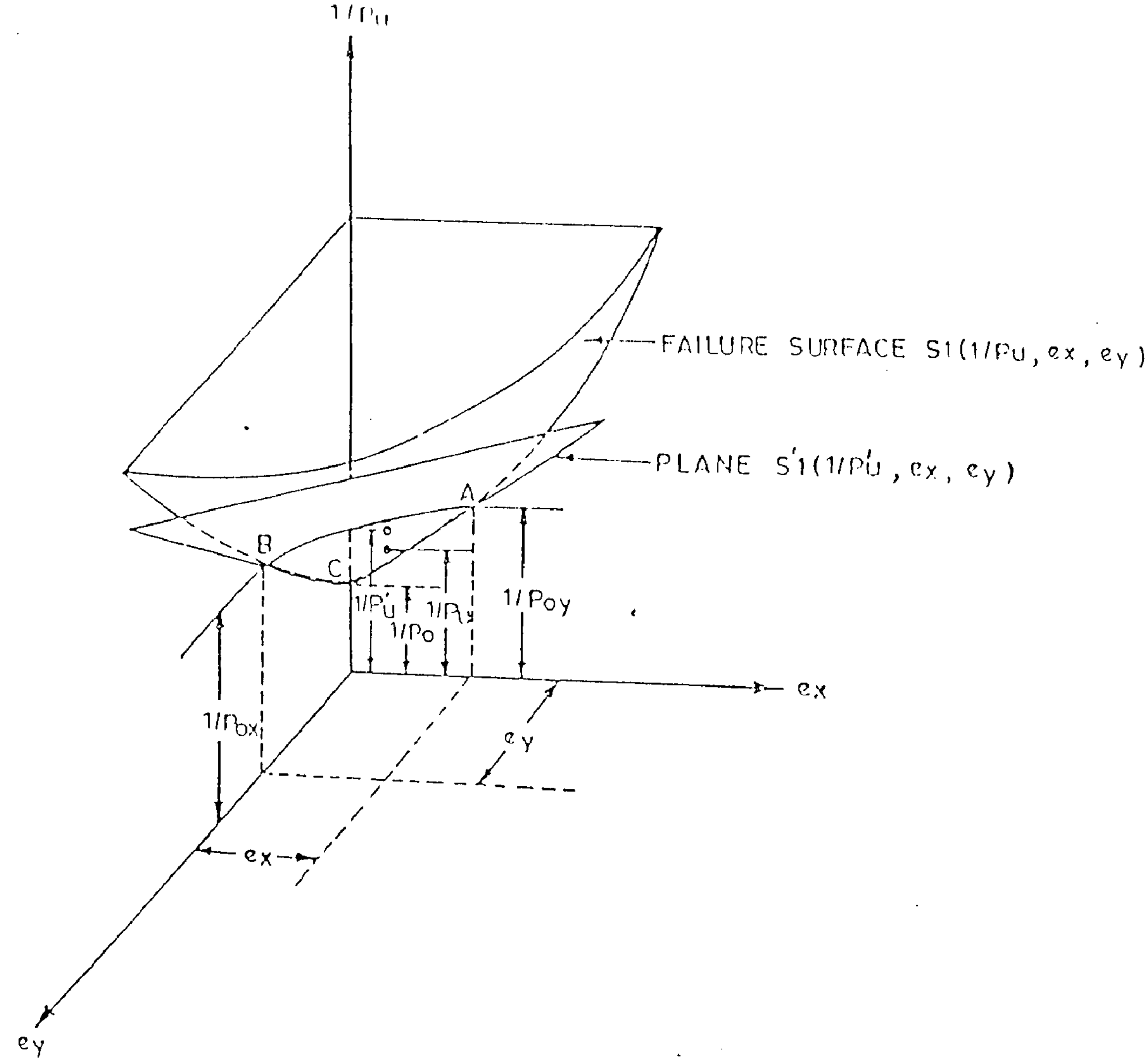


Fig.2.5 BRESLER'S RECIPROCAL LOAD APPROACH

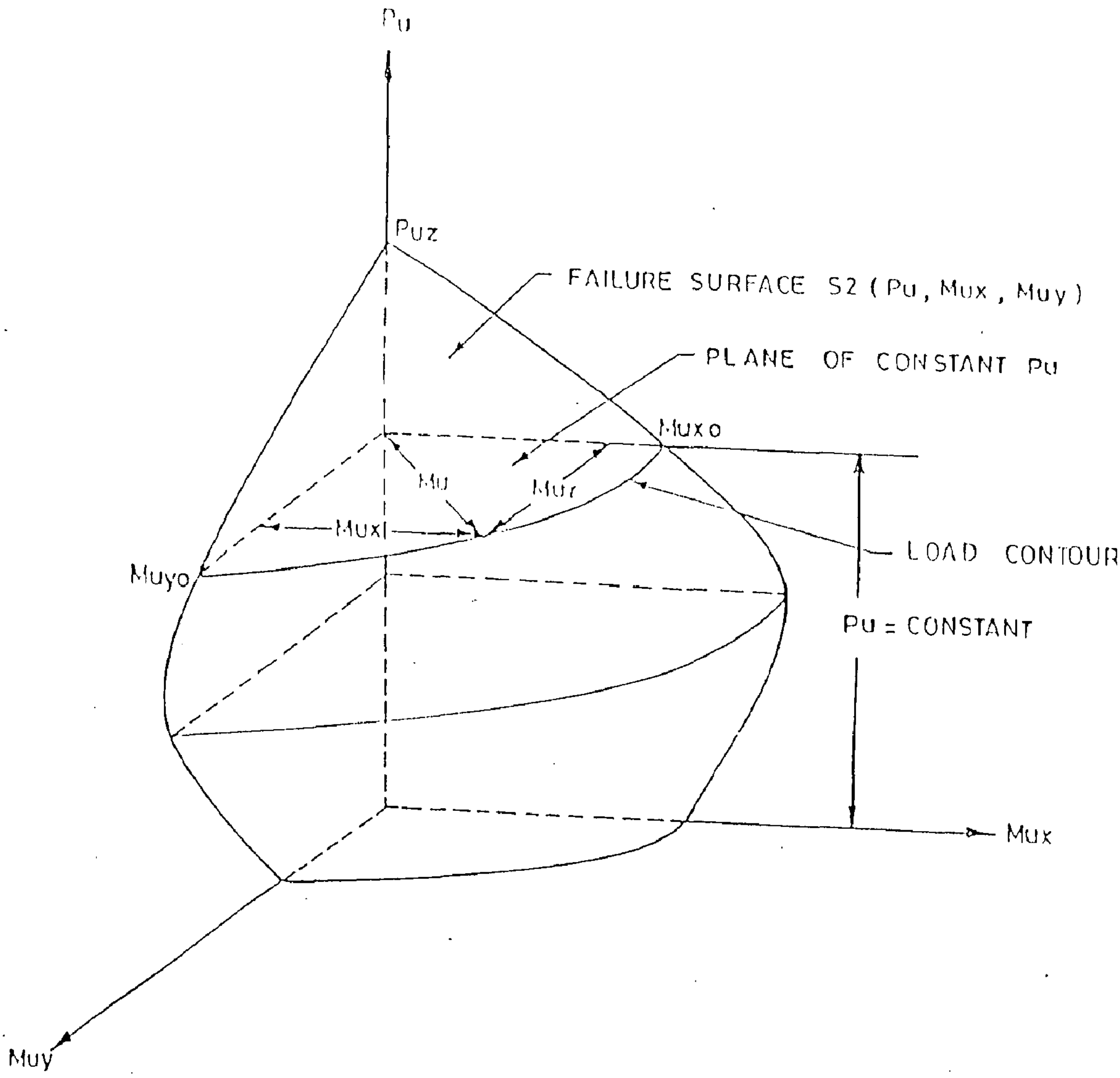


Fig.2.6 BRESELER'S LOAD CONTOUR

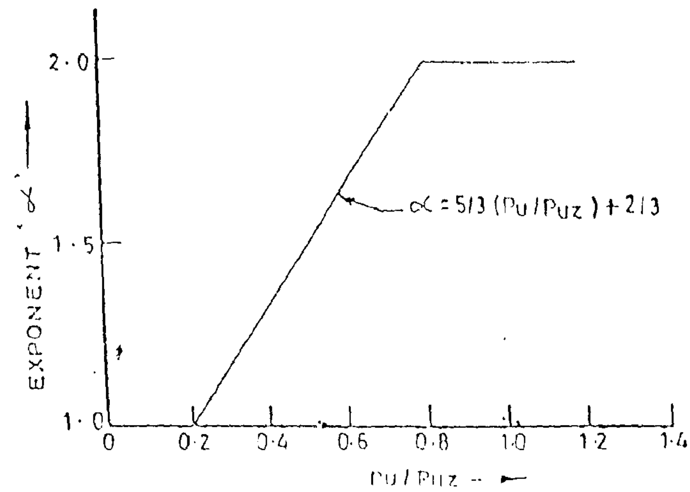


Fig.2.7 VARIATION OF EXPONENT α WITH Pu/Puz

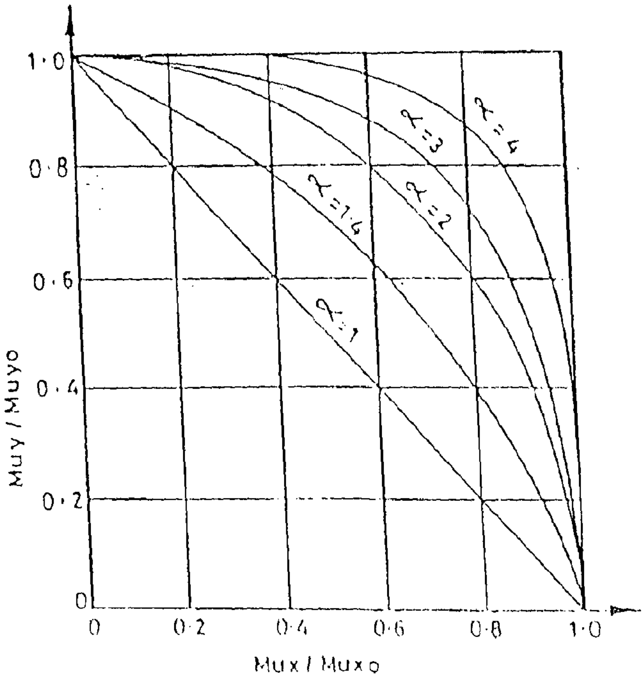


Fig.2.8 LOAD CONTOURS FOR VARIOUS VALUES OF 'α'

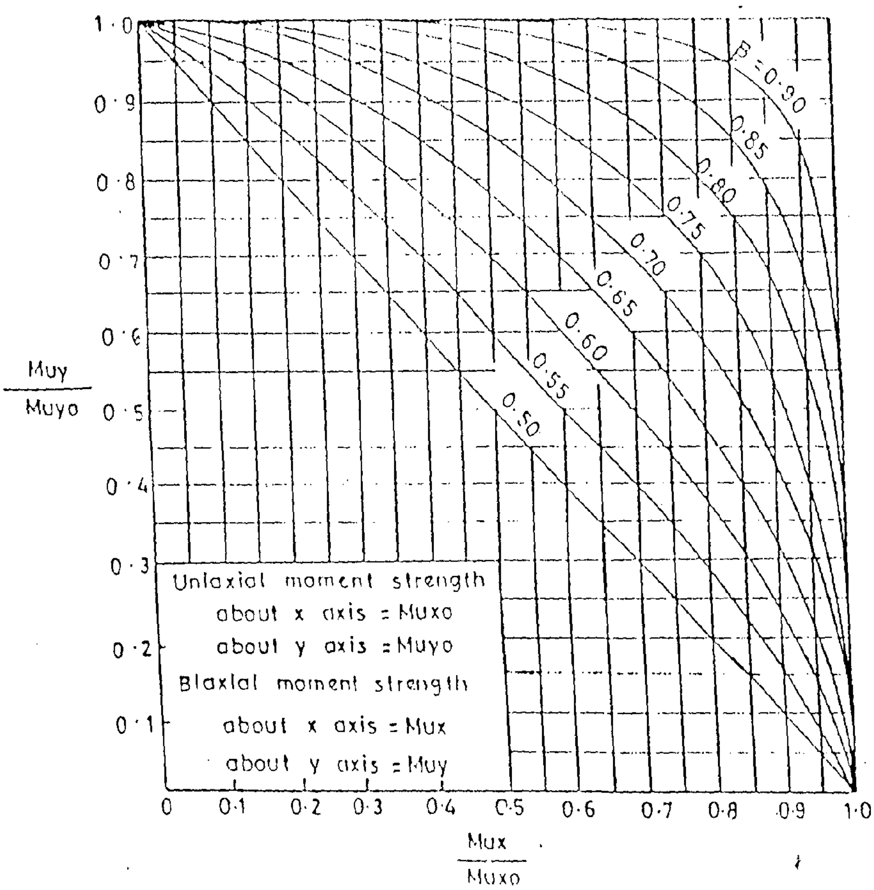


Fig.2.9 INTERACTION CURVES FOR DIFFERENT VALUES OF β

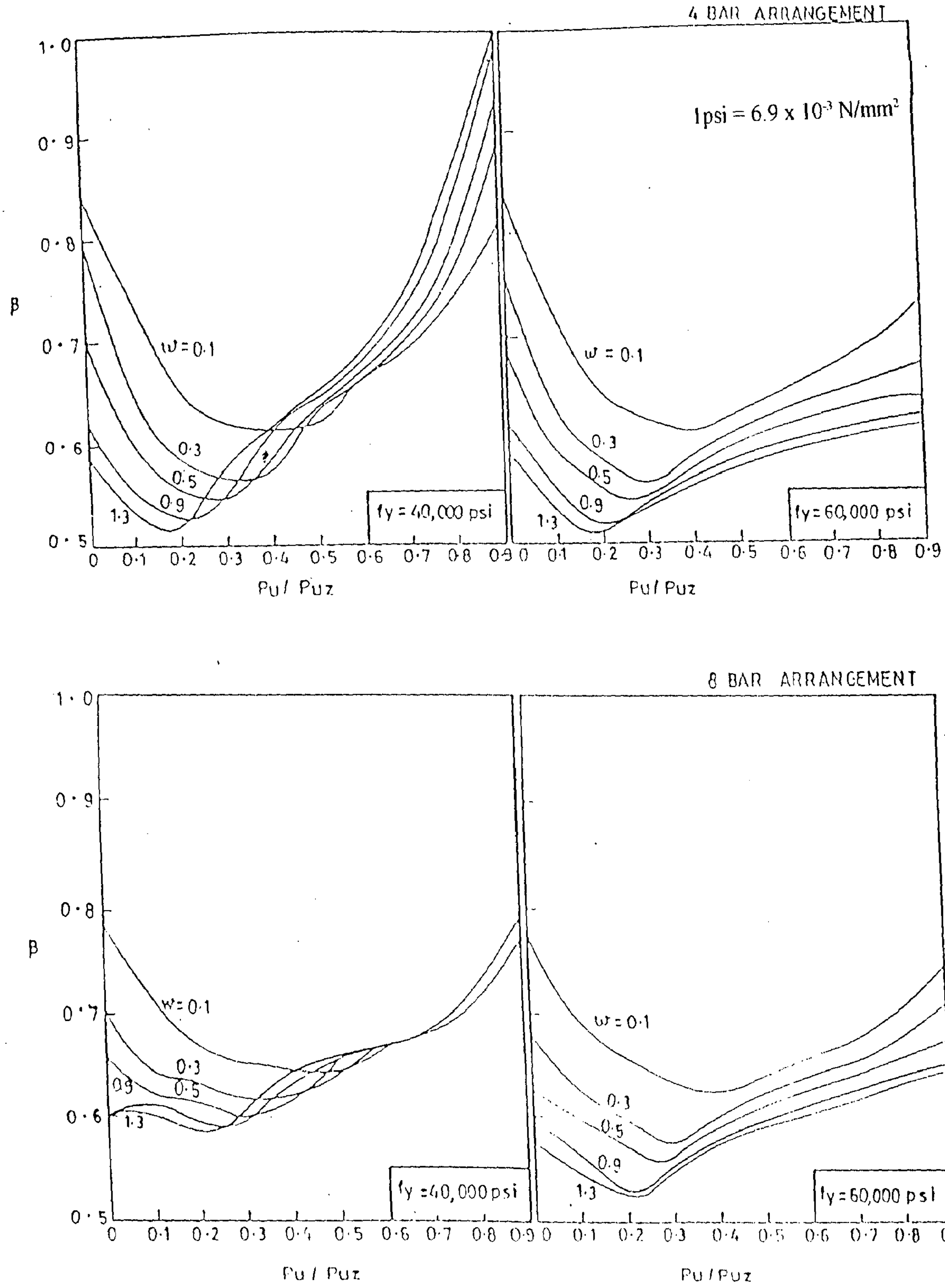


Fig.2.10 VARIATION OF β WITH Pu/Puz

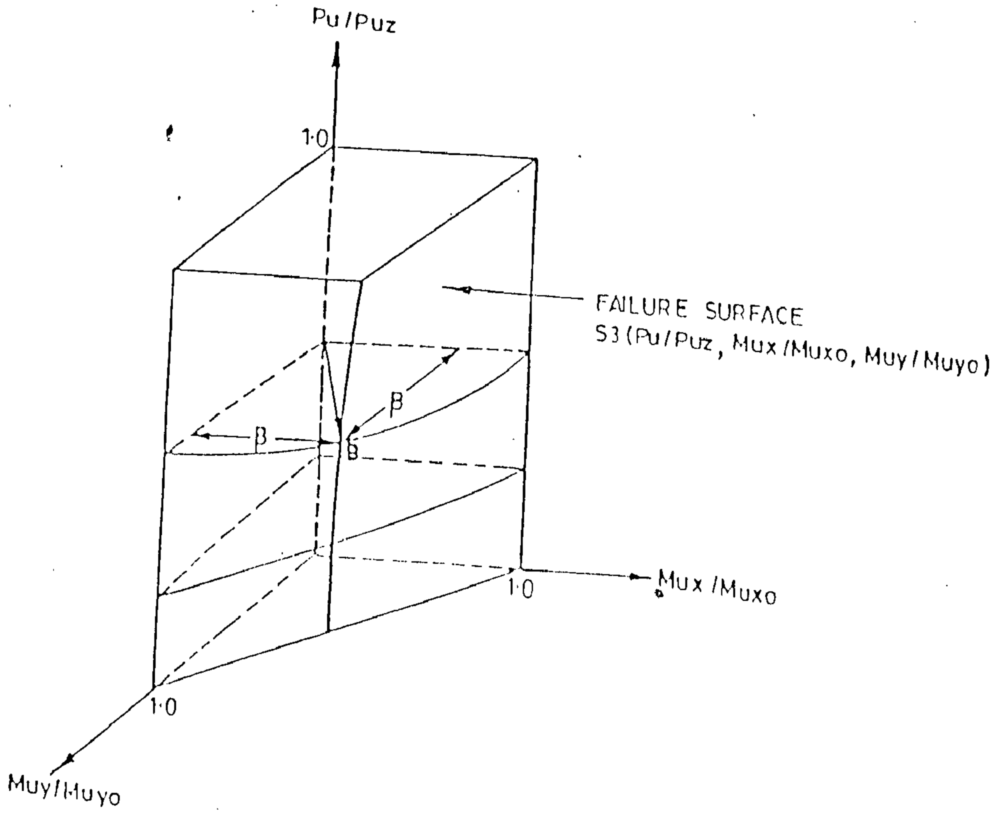


Fig.2.11 PCA LOAD CONTOUR APPROACH

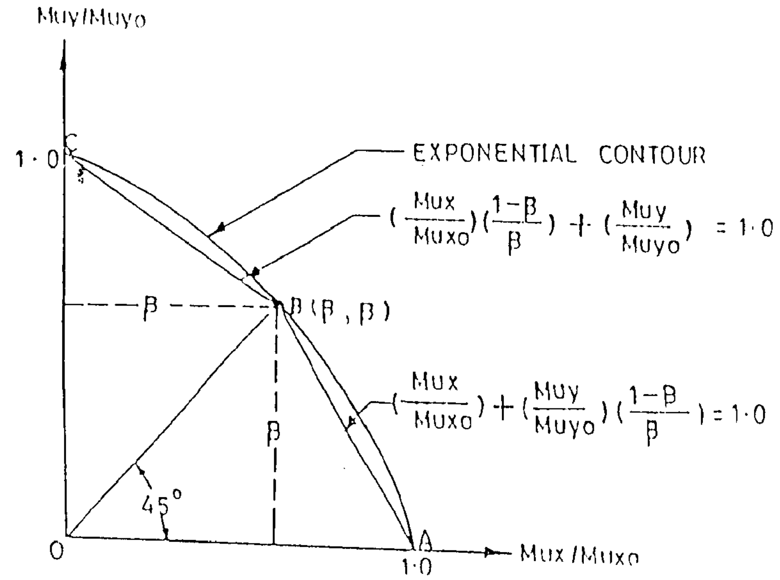


Fig.2.12 MEEK'S BILNEAR APPROXIMATION

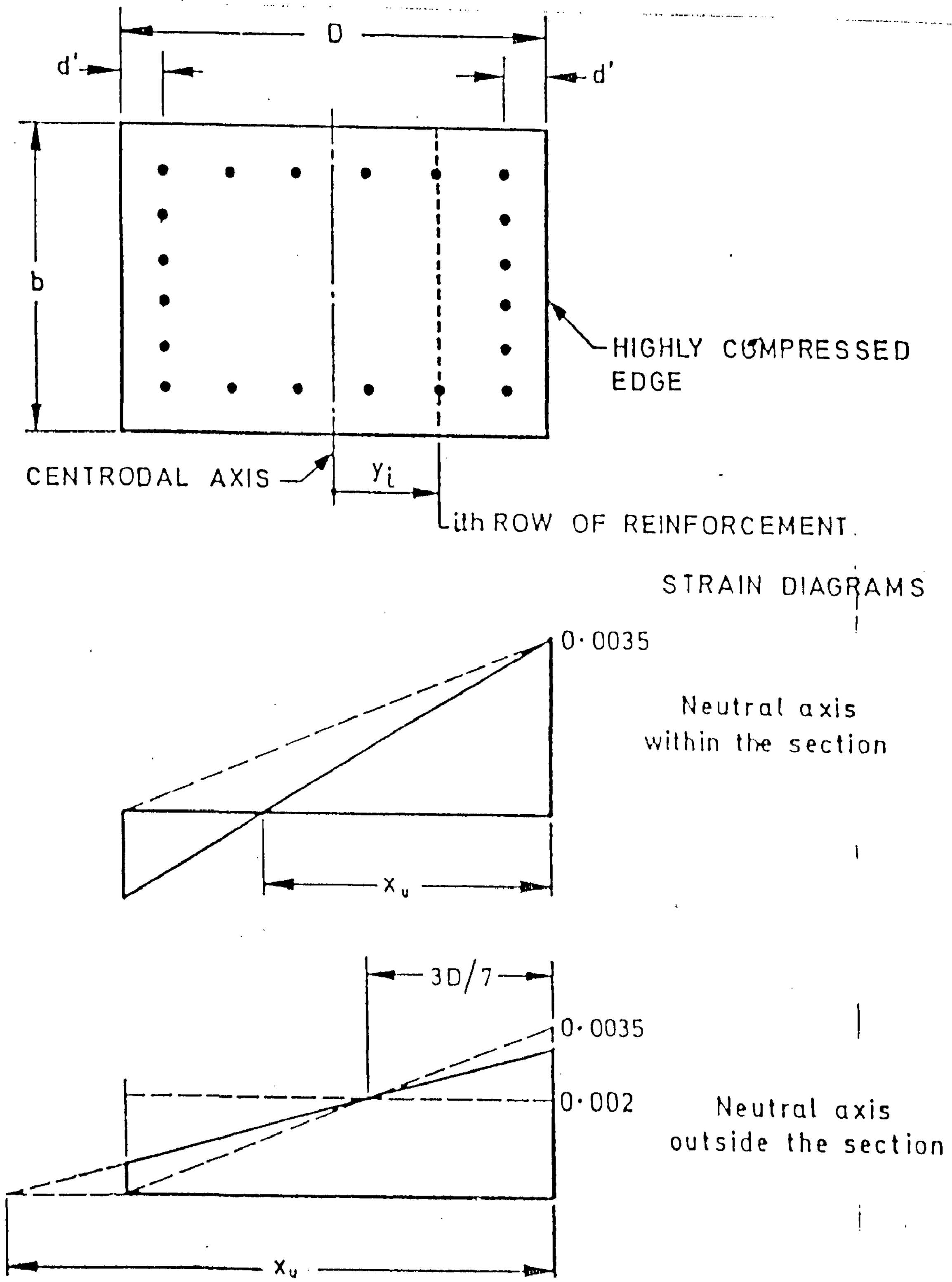


Fig.2.13 COMBINED AXIAL LOAD AND UNIAXIAL BENDING

TABLE 2.1 Coefficients Cc^1 and Yc^1 when the Neutral axis lies outside the section

$k = x_u/D$	Coefficient $C'_c = C_c/f_{ck}BD$	Coefficient $y'_c = y_c/D$
1.0	0.361	0.416
1.05	0.374	0.432
1.1	0.384	0.443
1.2	0.399	0.458
1.3	0.409	0.468
1.4	0.417	0.475
1.5	0.422	0.480
2.0	0.435	0.491
2.5	0.440	0.495
3.0	0.442	0.497
4.0	0.444	0.499

TABLE 2.2 Effective Length provisions of BS Code.

`End condition	Description
Condition1	The end of column is connected monolithically to beams on either side which are at least as deep as the overall dimension of the column in the plane under consideration. It simulates a fixed end condition.
Condition2	The end of column is connected monolithically to beams or slabs on either side which are shallower than overall dimension of the column in the plane under consideration. It simulates a hinged end condition.
Condition3	The end of the column is connected to members which, while not specifically designed to provide restraint to rotation of the column,still provides some nominal restraint. It simulates a hinged end condition.
Condition4	The end of the column is unrestrained against both lateral movement and rotation. It simulates free end of a cantilever in an unbraced structure.

TABLE 2.2 (a)

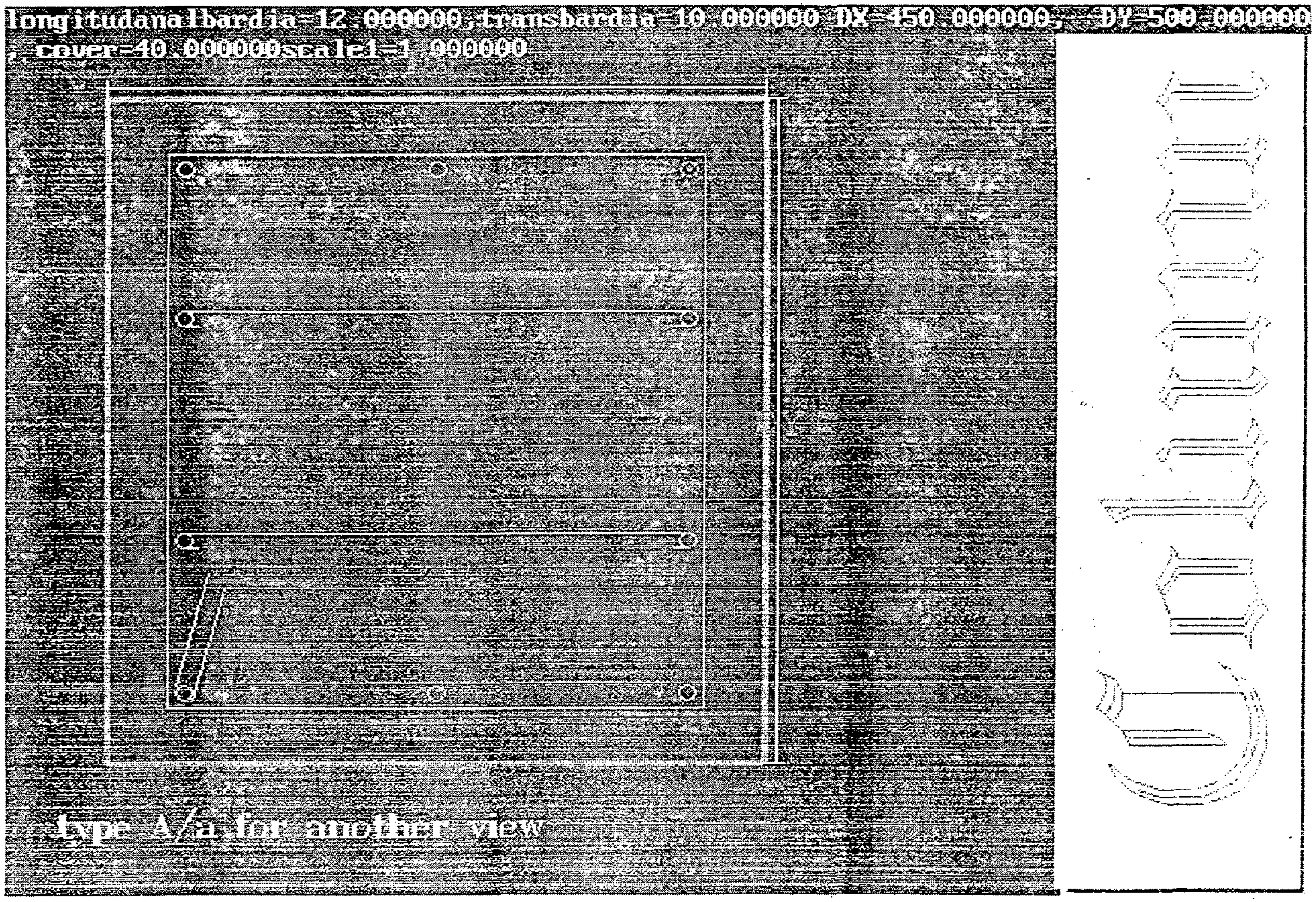
Value of z for braced columns

End condition at top	End condition at bottom		
	1	2	3
1	0.75	0.80	0.90
2	0.80	0.85	0.95
3	0.90	0.95	1.00

TABLE 2.2 (b)

Value of z for unbraced columns

End condition at top	End condition at bottom		
	1	2	3
1	1.2	1.3	1.6
2	1.3	1.5	1.8
3	1.6	1.8	--
4	2.2	--	--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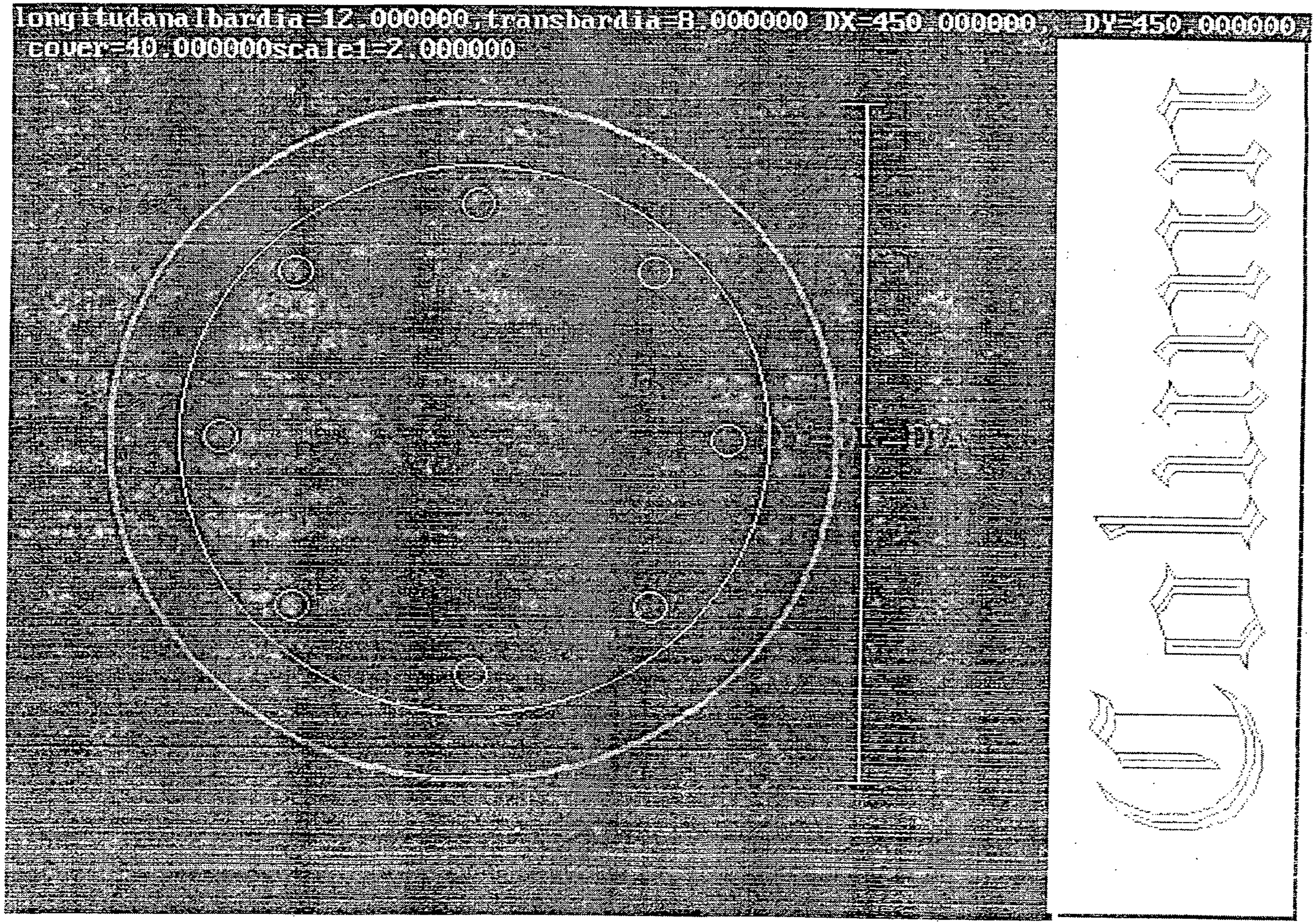
type A/a for another view
Column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