1620 GENERAL PROGRAM LIBRARY

Column Analysis Under Axial Load And 2-Way Bending

9.2.022

COLUMN ANALYSIS

UNDER

AXIAL LOAD & 2-WAY BENDING

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Modifications or revisions to this program, as they occur, will be announced in the appropriate Catalog of Programs for IBM Data Processing Systems. When such an announcement occurs, users should order a complete new program from the Program Information Department.

DECK KEY

Deck	1	Fortran w/Format-Object Prog.
Deck	2	Listing Program
Deck	3	Col. Anal. Fortran Source
Deck	4	List Program for Source
Deck	5	Test #2 Output

PROGRAM DESCRIPTION

PURPOSE

This program performs the analysis of a reinforced concrete column under axial loading and moment in two directions (two-way moment). The program will also handle the analysis of a column under axial load and bending in one direction (one-way moment).

METHOD

The program goes through four general phases. The first is the location of the XX and YY axis (see fig.1). The second is the computation of moments of inertia about the XX and YY axis. The third is the calculation of stresses for the four corners of the column and for the steel bar under maximum tensile stress. Phase four is the calculation of the neutral axis location based upon the stresses computed in phase three. The initial assumption for the neutral axis may differ greatly from the location computed in phase four. The user therefore has the option of a new analysis using the neutral axis location just computed as the assumed neutral axis location. This may be continued as often as necessary until close agreement is secured between the assumed neutral axis location and the computed neutral axis location.

Input data for the analysis of a column is contained in three cards (see Page one).
Card one contains the following information:

1. X and Y dimensions of the column (see fig.1)col. may be square or rectangular.

2. Data covering location of steel reinforcing bars. Cover distance and bar spacing in X and Y directions are given here. Bar spacing is assumed to be the same along AB and DC edges (see fig.1). Bar spacing is assumed to be the same along AD and BC edges. One row of reinforcing is assumed along all four column faces (see fig.1).

3. The assumed location of the XX and YY axis.

Card two contains the following data:

1. Dimensions defining the points where the assumed neutral axis crosses the column edges (see fig.1).

2. The area of the reinforcing used. This is the

area of one bar. All reinforcing is assumed to be uniform in size.

3. The axial load and the bending moments about the locations assumed for the XX and YY axis.

4. The number of reinforcing bars in the X direction along column edges DC and AB and the number of reinforcing bars in Y direction along column edges AD and BC. Corner bars are included in both counts. In figure 1 the column shown has 12 bars in both the X and Y directions.

Card three contains the following:

1. The ratio of flexural modulus of elasticity for reinforcing steel to flexural modulus of elasticity for concrete and the fore-mentioned ratio minus one.

The effect of steel reinforcing bars upon the transformed section varies according to whether the bar in question is in tension or compression. In the first case the ratio used is N, in the second case N-1 is used. To facilitate this determination, the dimensions RPX1,RPY1,RPX2, and RPY2 are computed (see fig. 2). RPX2 and RPY2 specify the location of point P2. P2 is the point where the assumed neutral axis crosses the center line of the steel reinforcing near point B. RPX1 and RPY1 specify the location of point P1. P1 is the point where the assumed neutral axis crosses the center line of the steel reinforcing near point D.

The program next performs the computation for finding the sum of the transformed area due to all reinforcing bars and the area moments about AD and DC. This is an iterative type procedure, beginning with the bar at corner D. Each bar is handled separately.

Row one reinforcing is considered first. The number of reinforcing bars in row one is NI. This number is data supplied by the user.

The minimum number of bars in row one or the last row is two. The program itself sets no limitation upon the maximum number of bars which may be in the row. This limitation is a practical one set by feasability of good and uniform construction. There is no program check as to whether the bar spacing supplied by the user is below the minimum allowed. There is also no program check as to whether the number of bars specified by the user may be included within the dimension DX with a cover distance of CV and bar spacing of CBX. The user must make this check himself.

For reinforcing bars in row one RY is constant and equal to CV. RY is the distance to the bar in question from DC. The key as to a bar being in tension or compression lies in its relationship to RPX1. If RX (the distance from AD to the bar in question - see fig. 1 & 2) is less than RPX1 the bar is in tension. If RX is greater than RPX1 the bar is in compression.

Reinforcing for rows 2- (NJ-1) are considered next. NJ is the number of rows of reinforcing steel and is specified by the user. For rows 2-(NJ-1) only two bars of steel exist, one in column one and one in column NI.

If the bar under consideration is in column one, the value of RX is CV. The critical dimension is RPY1. If RY is greater than RPY1 the bar is in tension. If RY is less than RPY1, the bar is in compression.

If the bar under consideration is in column NI, the value of RX is constant for all bars in the column. The critical dimension is RPY2. If RY is less than RPY2, the bar is in compression. If RY exceeds RPY2, the bar is in tension.

In row NJ the value of RY is constant for all reinforcing bars in the row. The key dimension is RPX2. If RX is less than RPX2, the bar is in tension. If RX exceeds RPX2 the bar is in compression.

If a bar is in tension it's area is multiplied by the ratio AN in computing its contribution to the transformed section. AN is the ratio n or ratio of flectural modulus of elasticity for reinforcing steel to flectural modulus of elasticity for concrete. For concrete having a compressive strength of 3000psc @ 28 days n is 10. If a bar is in compression, its' area is multiplied by (n-1) to compute its contribution to the transformed area. For each bar the following computations are done in phase one. First, its transformed area is added to the sum of the transformed areas (SUMA). Next, the moment of its transformed area about AD is added to the sum of transformed area moments about AD (SUMAX). Finally, the moment of its transformed area about DC is added to the sum of transformed area moments about DC (SUMAY).

After all steel reinforcing has been processed, the concrete area in compression is considered. In addition to its affect upon SUMA, SUMAX, and SUMAY the moment of inertia about X and Y axis through the centroid of concrete areas in compression is computed at this time. A glance at figure 3 of appendix shows three possible concrete areas. The program tests for the presence of each type and calculates its contribution. Each of the areas present has its own centroid. It is about the X and Y axis of these centroids that we compute Moments of Inertia at this time.

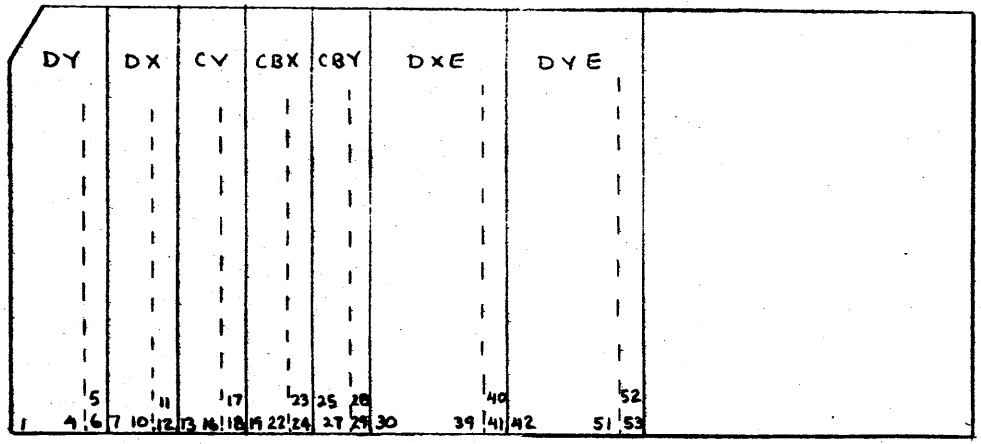
XBAR (the location of YY axis referred to AD) is computed by dividing SUMAX by SUMA. YBAR (the location of XX axis referred to DC) is computed by dividing SUMAY by SUMA. The revised moments about the XX and YY axis are now computed. These will differ from the original moments if XBAR and YBAR differ from DXE and DYE (assumed dimensions from AD and DC to point of action of axial load).

After locating the XX and YY axis for the column, the program is now able to compute the contribution of the steel reinforcing to the moments of inertia about the XX and YY axis. Once again a determination is made as to whether a bar is in tension or compression.

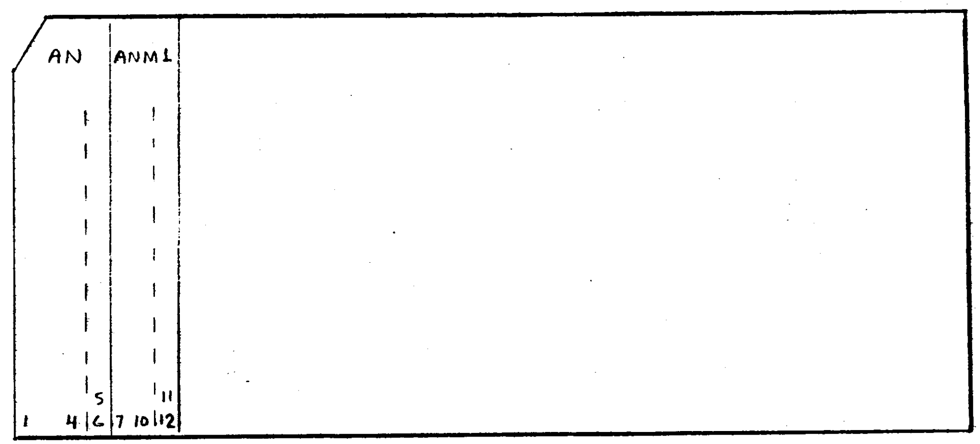
The concrete areas in compression contribute further to the moments of inertia because of the eccentricity or distance of their centroids from the centroid of the transformed section. This contribution equals the area times the distance squared.

Phase three of the program covers the actual computation of stresses, now that the characteristics of the transformed section have been calculated. The stress due to axial load (P/A) and the stresses due to moments (MC/I) are now computed. MC/I is determined for all four column edges. The stress at any corner is the sum of P/A, MyCy/Iy, and MxCx/Ix. The stress for the bar in corner A (see fig.1) is computed. This is the bar having maximum steel stress. Part of the input supplied to the program by the user were four dimensions describing the location of the neutral axis assumed for purposes of analysis. The location of the neutral axis is computed in phase four based upon the stresses computed in phase three. If the computed location agrees closely with the assumed location, the section characteristics and stresses computed are close approximations of the actual values. If there is a large discrepancy, the section characteristics and stresses differ widely from the actual. The two examples shown in appendix bear this out.

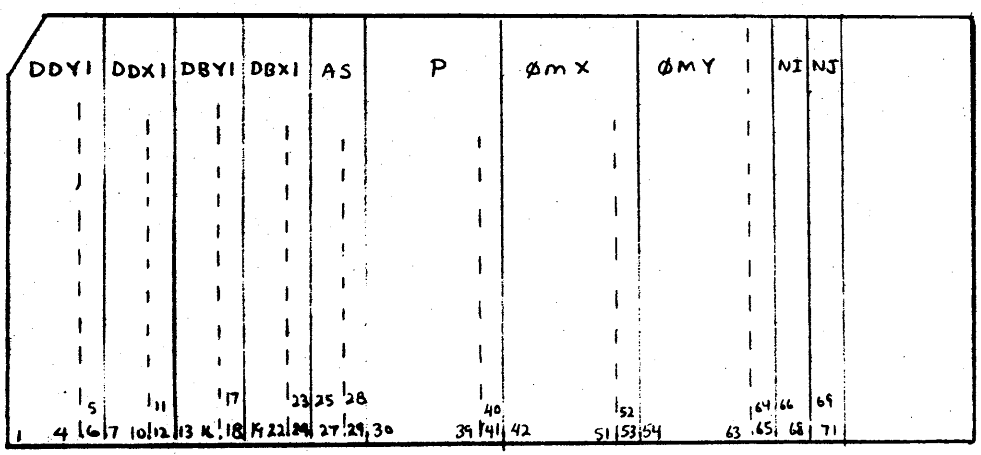
The computer will stop calculations after phase four. The printed output obtained at all phases is shown in the description of typed output records on pages 8 to 9. The last line given shows the computed neutral axis location. Should this differ widely from the assumed and should the user wish to perform another analysis, he need only push start. The computed neutral axis location will be used as the assumed neutral axis location in a new analysis. This procedure may be continued as often as required. Example 2 shows that the number of iterations required is not large even when a bad guess is made as to neutral axis location for our initial assumption.



INPUT CARD 1



INPUT CARD 3

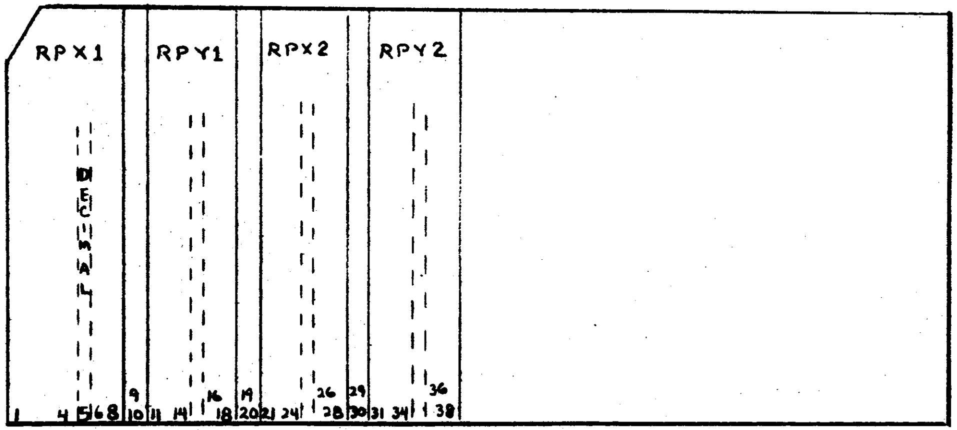


INPUT CARD 2

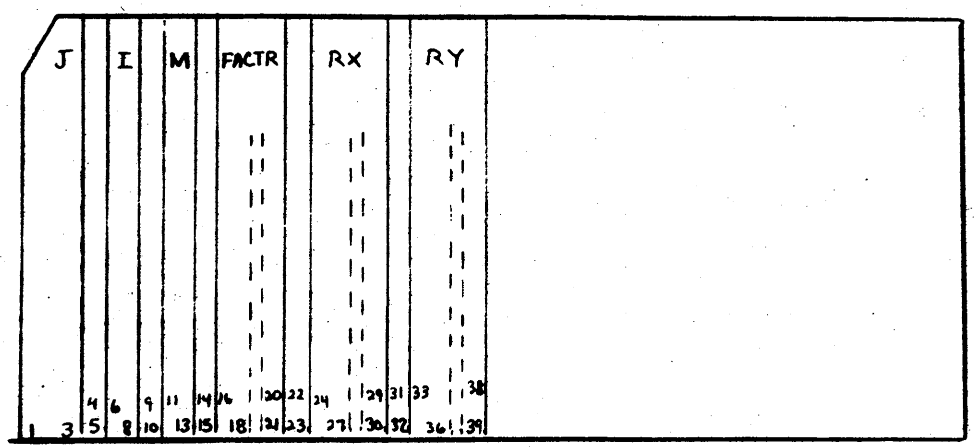
<u>Typed Output Records</u>
(see appendix for symbol explanations)

Record 1	SUMA SUMAX SUMAY	
Record 2	AC (3) SUMAY SUMAX SMRIY SMRIX	this record typed out only if concrete area 3 present (see fig.3)
Record 3	AC (2) SUMAY SUMAX SMRIY SMRIX	this record typed out only if concrete area 2 present (see fig.3)
Record 4	AC (1) SUMAY SUMAX SMRIY SMRIX	
Record 5	XBAR YBAR	
Record 6	SUMA ØMYR ØMXR	
Record 7	SMRIY SMRIX	
Record 8	ARKY ARKX SMRIY SMRIX	for concrete area L
Record 9	ARKY ARKX SMRIY SMRIX	for concrete area 3 if present
Record 10	ARKY ARKX SMRIY SMRIX	for concrete area 2 if present

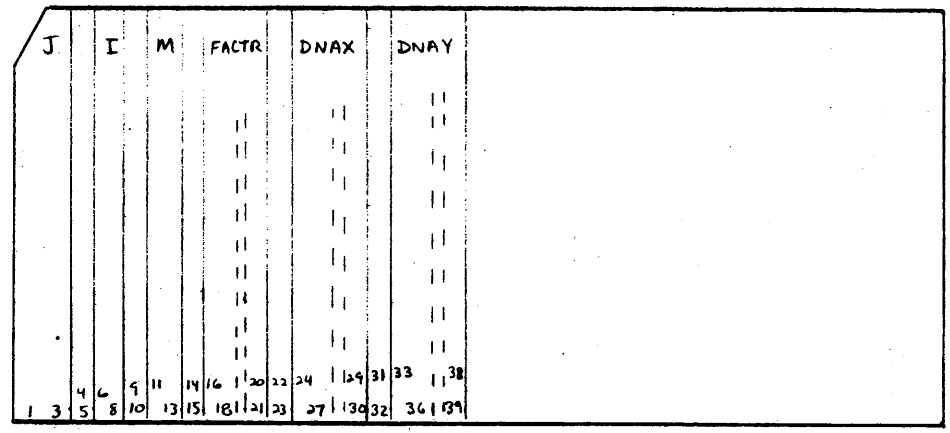
Record 11	ØMIY ØMIX TSADY TSBCY TSDCX TSABX	
Record 12	SA SB SC SD SST	
Record 13	DDYI DDXI DBYI DBXI	typed at end of each iteration computed neutral axis location



OUTPUT CARD 1



OUTPUT CARD 2



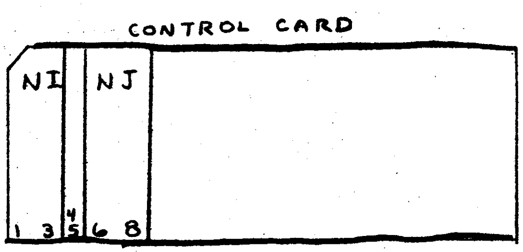
OUTPUT CARD 3

PROGRAM DESCRIPTION -- LISTING PROGRAM

PURPOSE: To save time the detail information concerning steel reinforcing, its effect upon the location of XBAR and YBAR, and its contribution to moment of inertia about X & Y axis is punched into cards. This program is to list this detail data if desired.

INPUT: Output card types 1, 2 and 3 from the column analysis program.

OUTPUT: RPX1, RPY1, RPX2, RPY2 on line 1. J, I, M, Factor, X & Y location of each bar. This is output from the computation of XBAR and YBAR. J, I, M, Factor, X & Y distances of each bar from the X and Y neutral axis.



Programming Notes:

1. Origin of the object program is 8000.
   Address at end statement is 17442 (see Appendix C).
   Address at symbol table end is 18319 (see Appendix C).
   There is therefore little room for additions to the program. If changes are made, it is imperative that the compiler be altered to begin origin at 8000. Technical Bulletin No. 84 for the 1620 covers the required changes.

2. Compilation and running assumes the availability of the automatic divide feature. Compilation for use on a machine without automatic divide requires origin at 8300 and will result in overlap condition in the present form of the source program.

3. The object program does not have the subroutines compiled. These must be loaded at running time after the object program is loaded.

4. Corner A must be in tension.
   Corner C must be in compression.

Running the Program (Main Program)

1. Clear Memory
   Reset
   Insert
   26 00008 00009
   Release
   Start
   After 2 seconds, instant stop
   Reset

2. Place object program in reader hopper.
   Press Load Key of card reader.

3. The reader will stop with the last two cards unread.
   Hit reader start to permit loading of the last two cards.

4. After the object deck has been loaded, the message "Enter Subroutines, Push Start" will be typed.

5. Place Subroutines Deck with Automatic Divide in reader hopper.
   Press reader start and console start. See (3). This also applies here. The message "1620 Fortran Sub. Auto. Div. 9/30/61" will be typed.

6. After the subroutine deck has been processed and the required subroutines have been loaded, the message "Load Data" will be typed.

7. Place data cards in the reader hopper.
Press Punch Start.
Press reader start and console start.

8. See (3). This also applies here. To avoid this condition two blank cards may be inserted after the three data cards. When the reader stops all data will have been read and processed. Then hit non-process runout to clear read feed.

9. The computer will perform the analysis of the column using the assumed neutral axis location read from the input data cards. A neutral axis location will be computed based upon the concrete stresses computed for the four corners A,B,C, and D. The computer will halt at the end of the first iteration.

10. Should another iteration be desirable, press console start. Another analysis of the column will be performed using the neutral axis computed on the previous iteration as the assumed neutral axis.

11. Step 10 may be repeated as often as desired.

12. After the last iteration has been completed, lift remaining blank cards from punch feed and hit non-process runout. Remove output cards from stack and hold. The last two cards are blanks.

13. To process another column, two options are available.

14. If data cards are placed in reader feed for one column at a time, place data cards for new column in reader hopper. Press punch start. Press reader start and console start. Steps 8 - 12 are applicable here.

15. If data cards are placed in reader feed for more than one column at a time, step 8 applies only to the last column to be analyzed. To start analysis of next column press punch start and console start. Steps 9 - 12 are applicable here.

<u>Running List Program</u>*

1. The output cards removed in step 12 of operation of the main program contain detail data on the contribution of the steel reinforcing during phases I and III. This program will list these cards if it is so desired.

*Control card must be inserted before data cards (see pg. 12)

2. Steps 1 - 8 of the operation procedures for the main program apply here also.

3. The computer will halt after listing the output cards from the first iteration. To list the cards from the succeeding iteration, press start.

4. Step 3 should be repeated until output cards from last iteration have been listed.

5. To list output cards from the analysis of another column, place cards in reader hopper, hit reader start and console start.

APPENDIX A

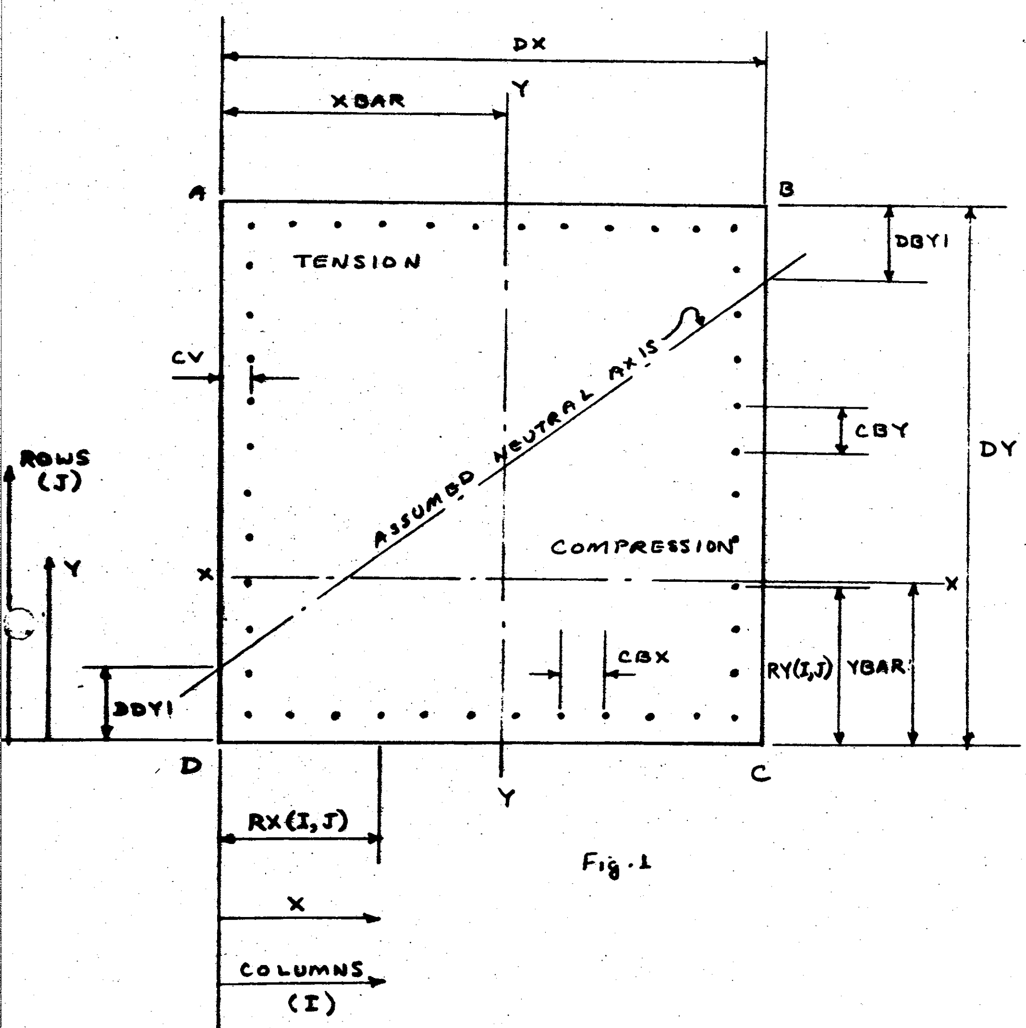


Fig. 1

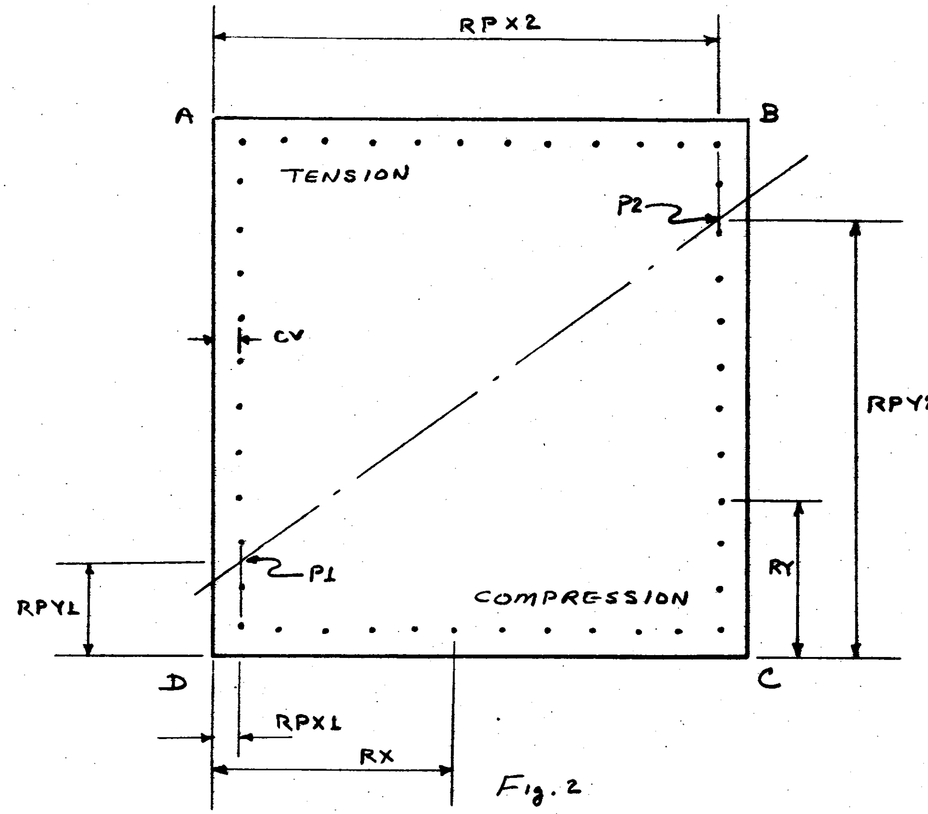


Fig. 2

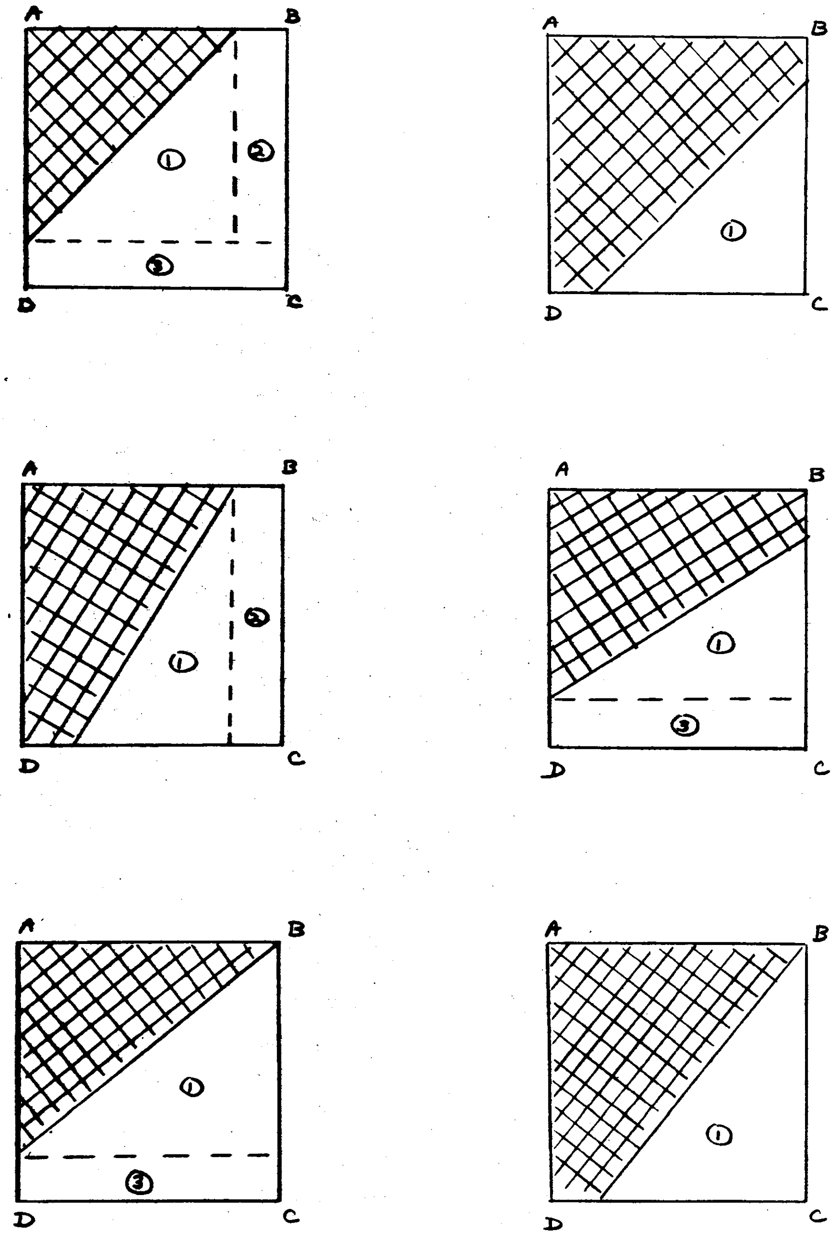


Fig 3

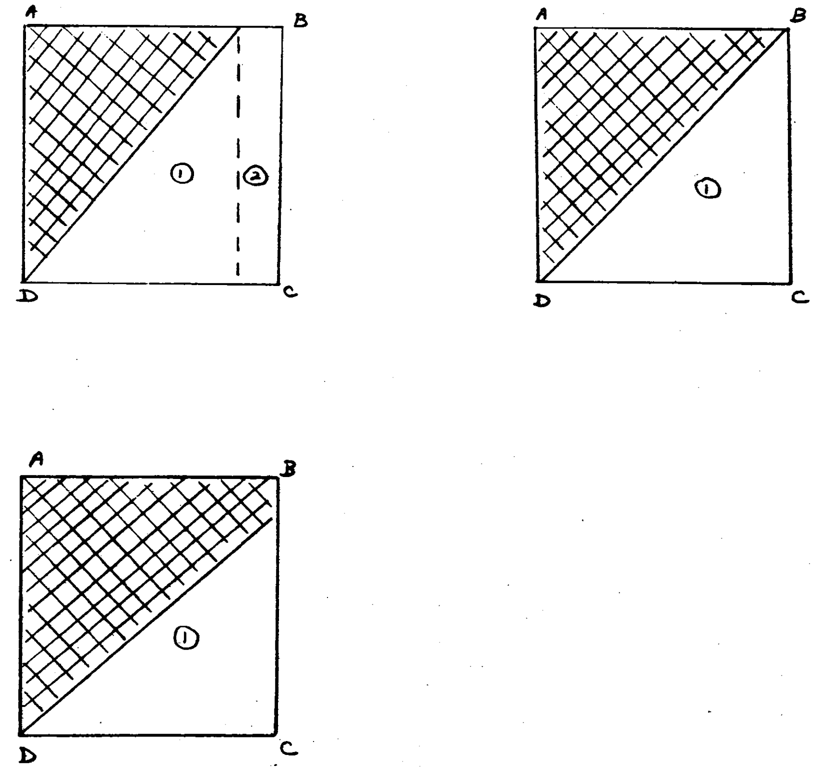
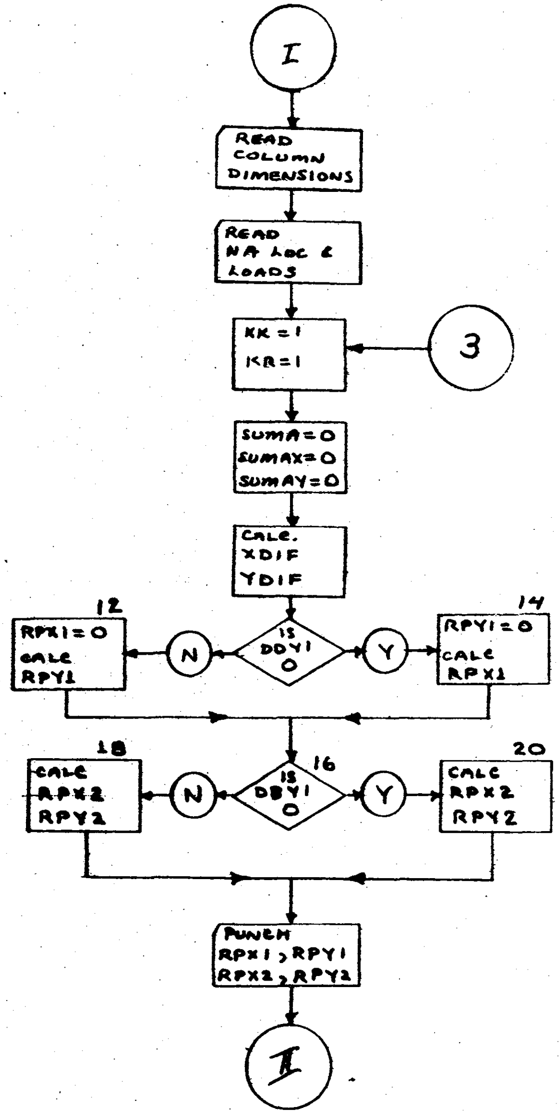
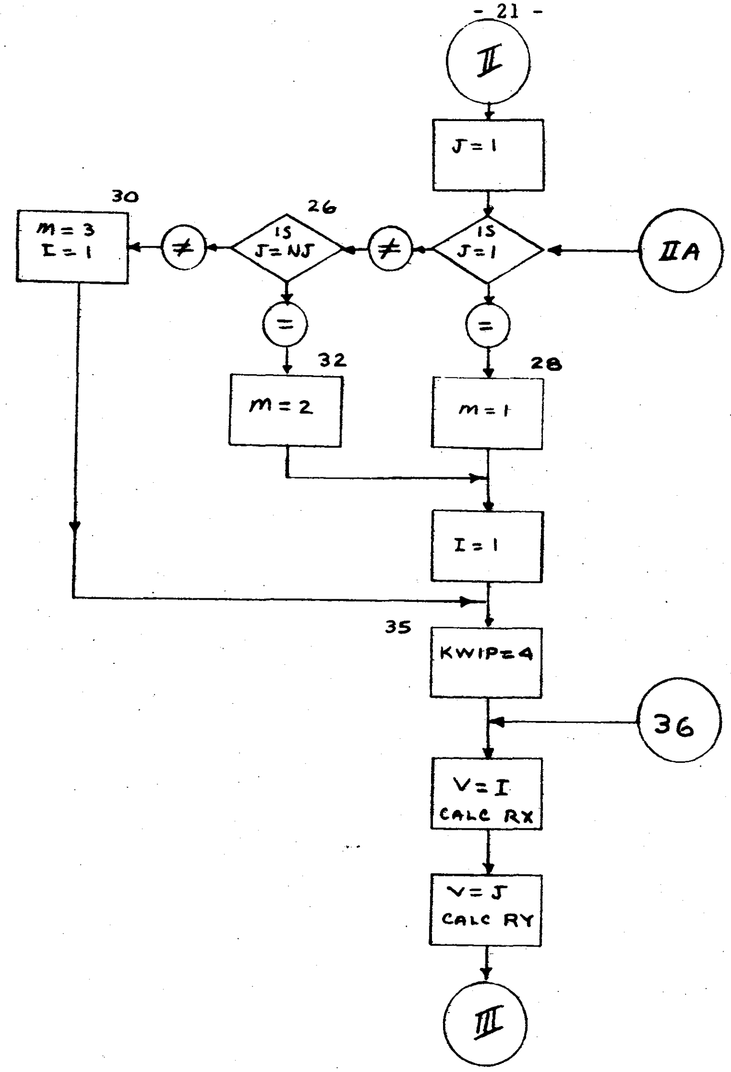


Fig 3 (cont.)

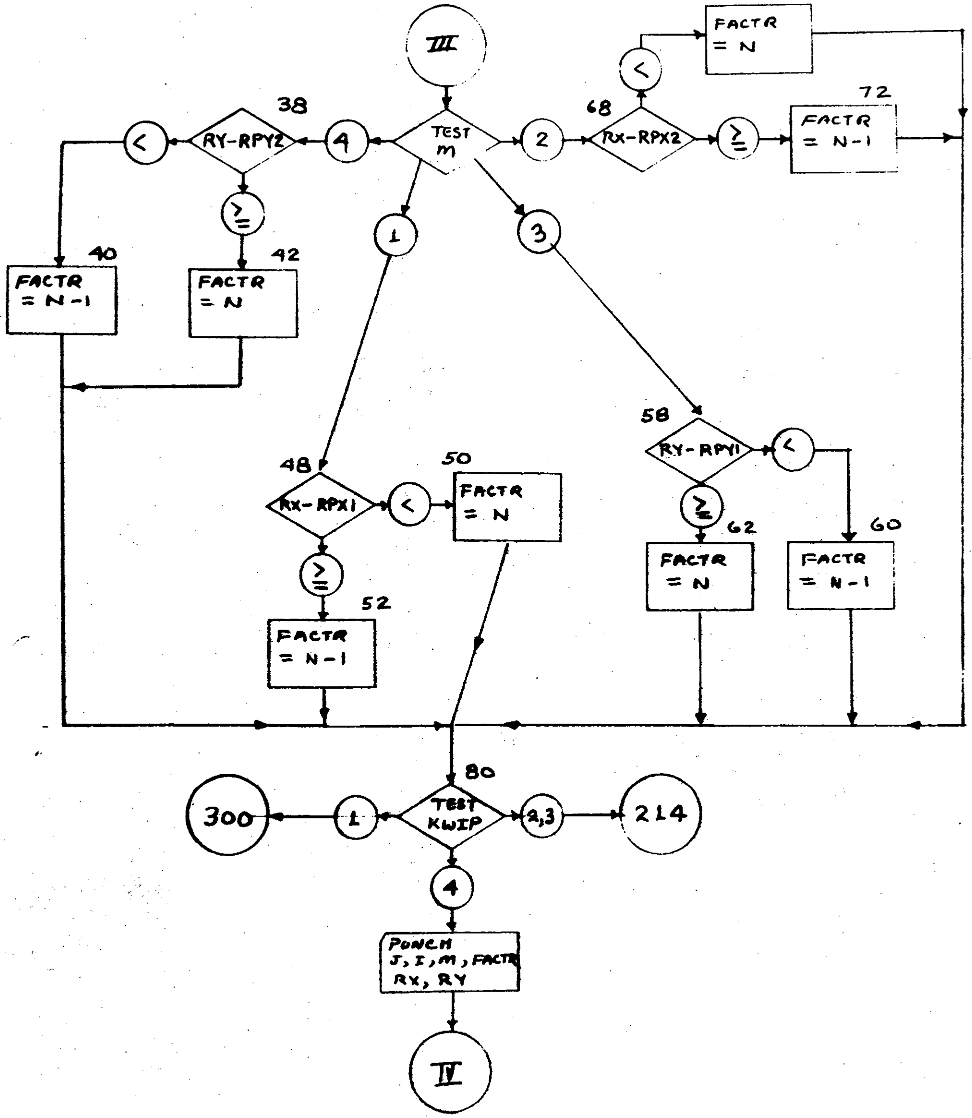
Appendix B

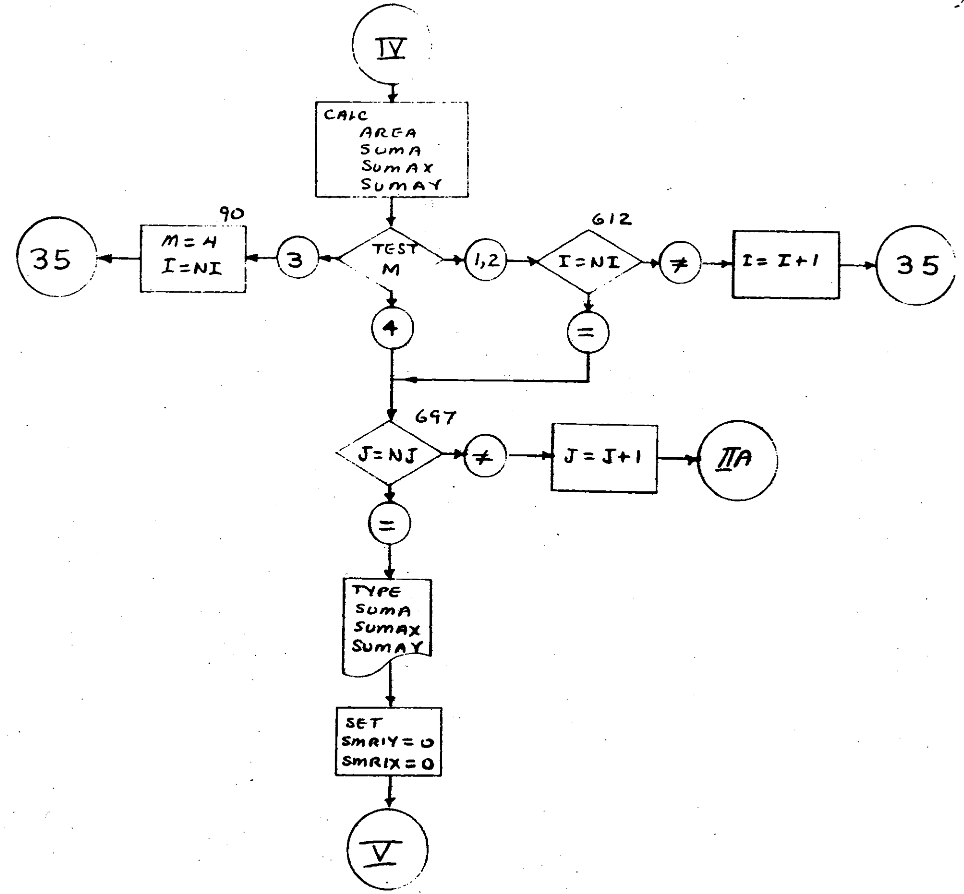


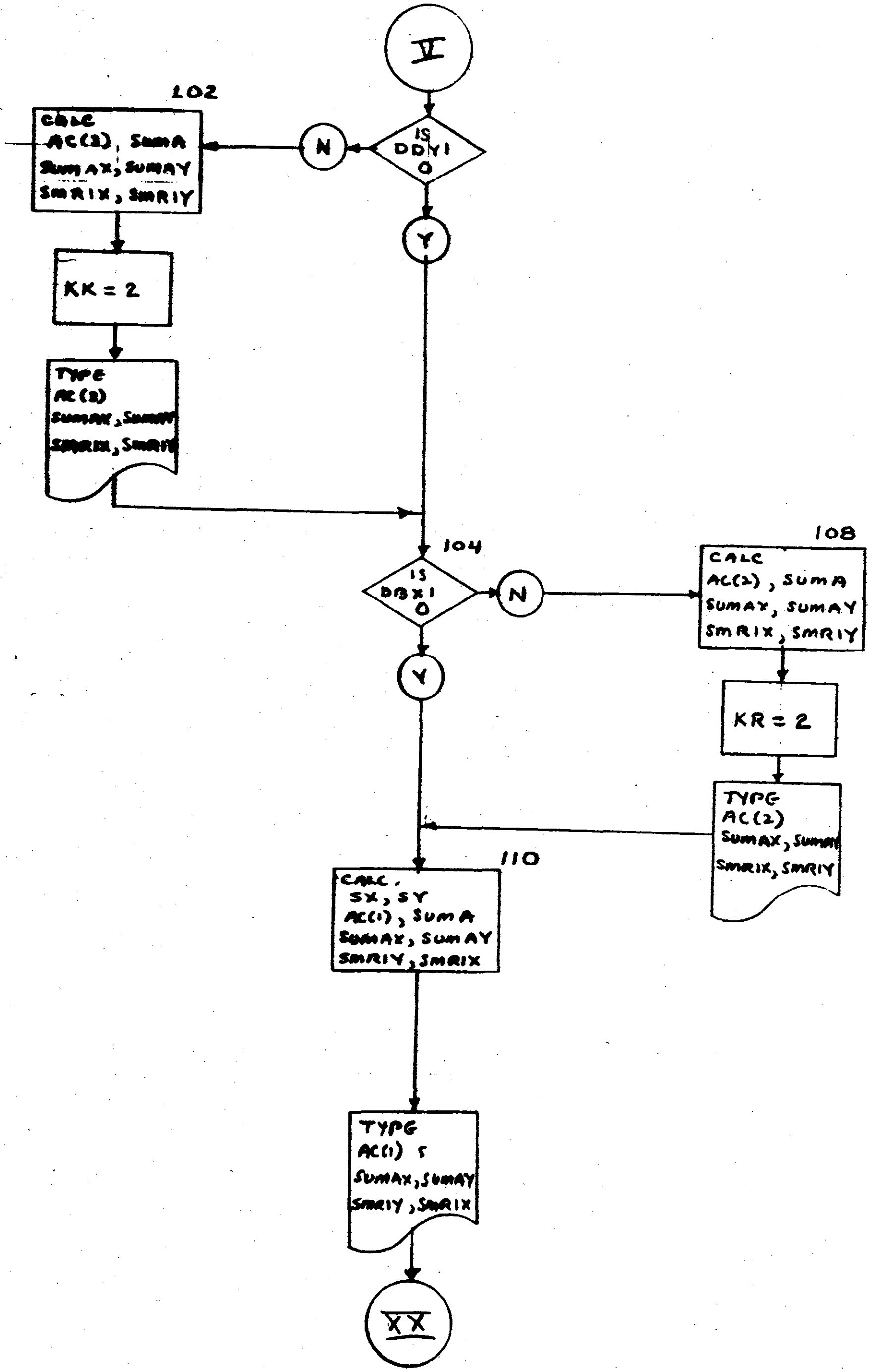
I
READ COLUMN DIMENSIONS
READ NA LOC & LOADS
KK = 1
KR = 1
3
SUMA = 0
SUMAX = 0
SUMAY = 0
CALC. XDIF YDIF
12
RPX1 = 0 CALC RPY1
N
IS DDY1 0
Y
14
RPY1 = 0 CALC RPX1
18
CALC RPX2 RPY2
N
16
IS DBY1 0
Y
20
CALC RPX2 RPY2
PUNCH RPX1, RPY1 RPX2, RPY2
II

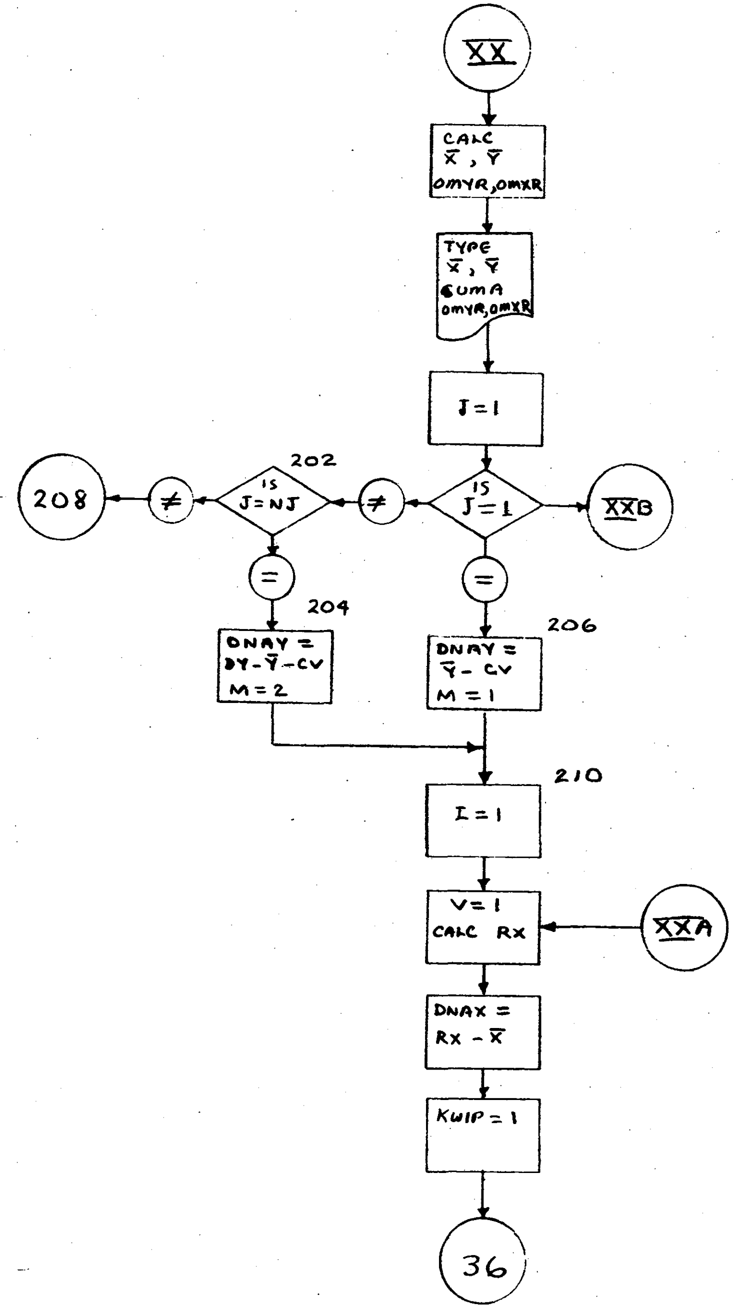


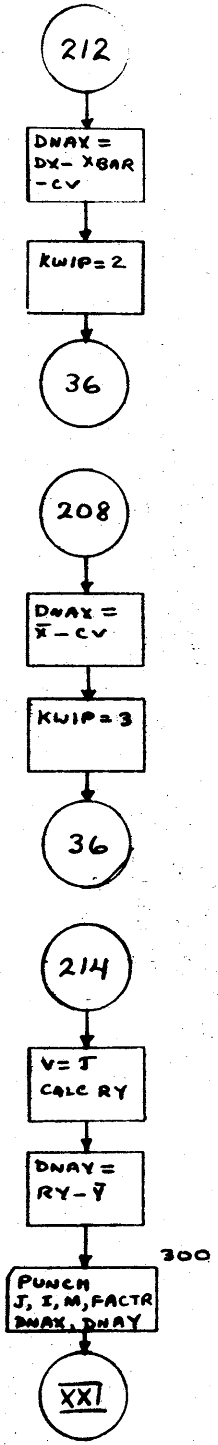
II
J = 1
30
m = 3 I = 1
≠
26
IS J = NJ
≠
IS J = 1
IIA
=
=
32
m = 2
28
m = 1
I = 1
35
KWIP = 4
36
V = I CALC RX
V = J CALC RY
III

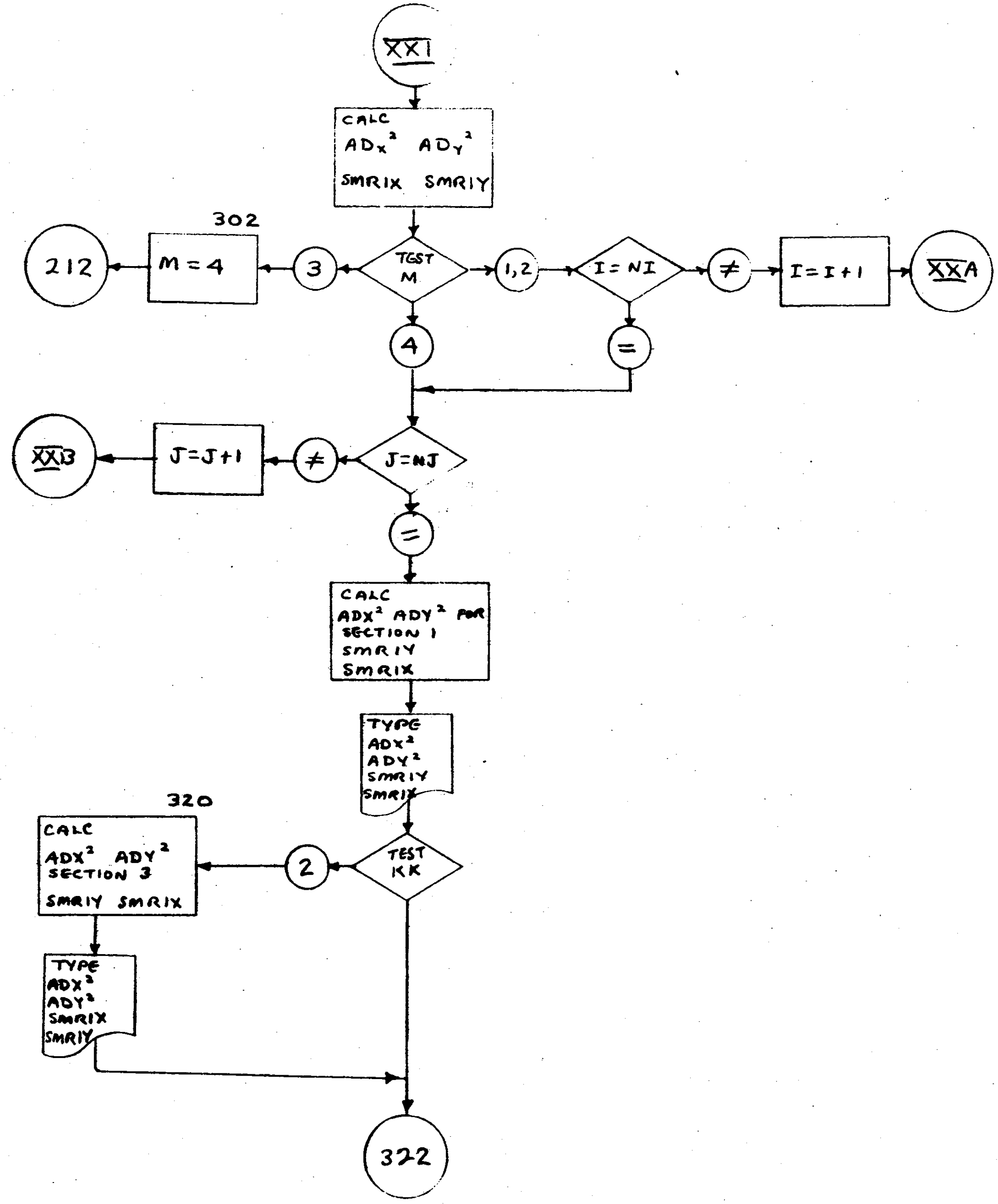

III
TEST
m
1
2
3
4
38
RY-RPY2
<
≥
40
FACTR
= N-1
42
FACTR
= N
68
RX-RPX2
<
≥
70
FACTR
= N
72
FACTR
= N-1
48
RX-RPX1
<
≥
50
FACTR
= N
52
FACTR
= N-1
58
RY-RPY1
<
≥
60
FACTR
= N-1
62
FACTR
= N
80
TEST
KWIP
1
2,3
4
300
214
PUNCH
J, I, m, FACTR
RX, RY
IV

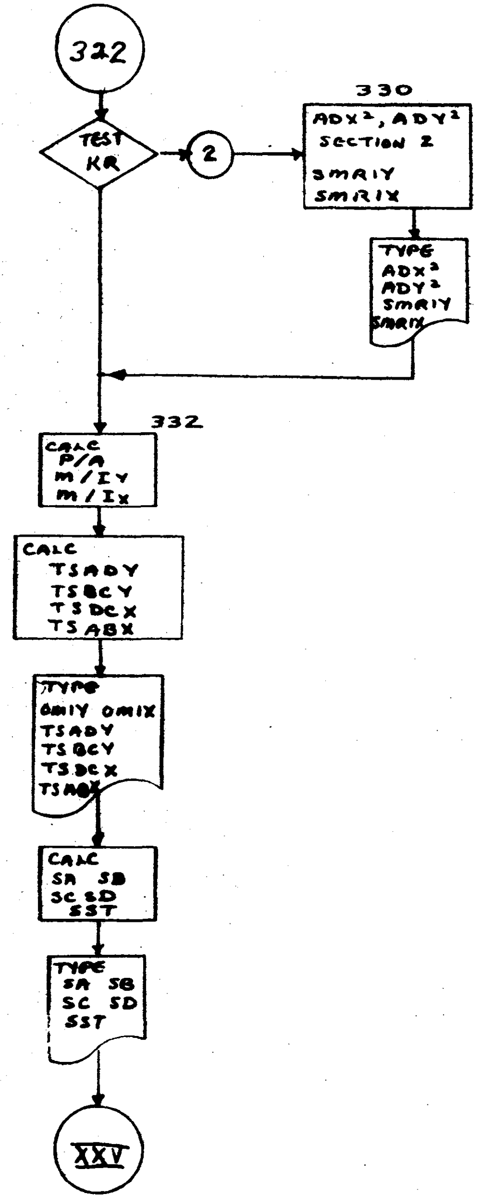

IV
CALC
AREA
SUMA
SUMAX
SUMAY
TEST
M
3
1,2
4
90
M = 4
I = NI
35
612
I = NI
≠
=
I = I+1
35
697
J = NJ
≠
=
J = J+1
IIA
TYPE
SUMA
SUMAX
SUMAY
SET
SMRIY = 0
SMRIX = 0
V

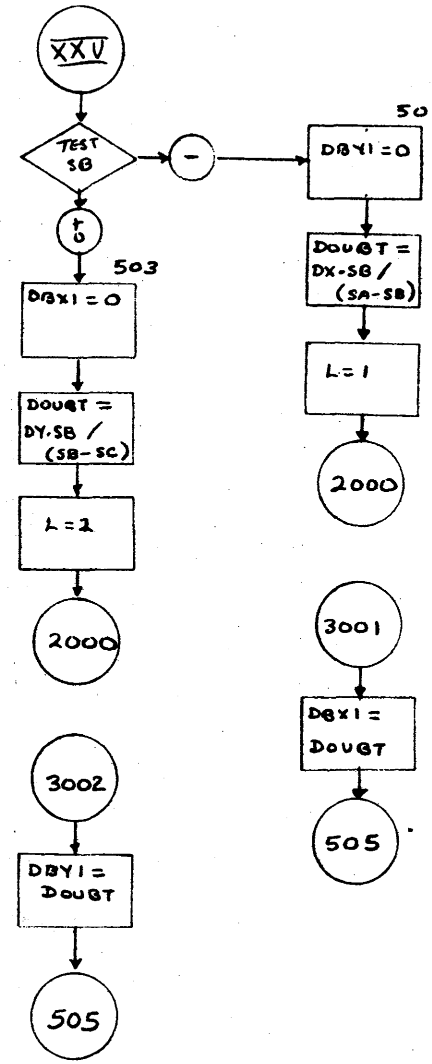

V
IS DDY1 0
N
Y
102
CALC AC(2), SUMA SUMAX, SUMAY SMRIX, SMRIY
KK = 2
TYPE AC(2) SUMAX, SUMAY SMRIX, SMRIY
104
IS DBX1 0
N
Y
108
CALC AC(2), SUMA SUMAX, SUMAY SMRIX, SMRIY
KR = 2
TYPE AC(2) SUMAX, SUMAY SMRIX, SMRIY
110
CALC. SX, SY AC(1), SUMA SUMAX, SUMAY SMRIY, SMRIX
TYPE AC(1) S SUMAX, SUMAY SMRIY, SMRIX
XX

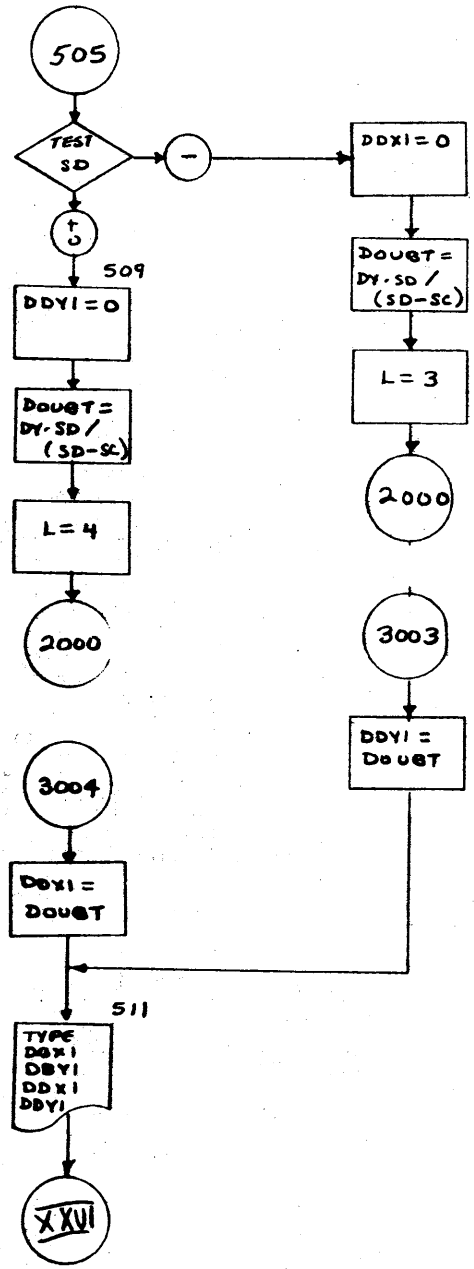

XX
CALC X̄, Ȳ OMYR, OMXR
TYPE X̄, Ȳ SUMA OMYR, OMXR
J = 1
IS J = 1
XXB
202
IS J = NJ
≠
208
=
204
DNAY = DY - Ȳ - CV M = 2
206
DNAY = Ȳ - CV M = 1
210
I = 1
V = 1 CALC RX
XXA
DNAX = RX - X̄
KWIP = 1
36

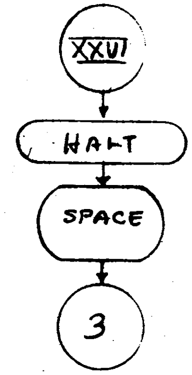

212
DNAX = DX- XBAR -CV
KWIP=2
36
208
DNAX = X̄-CV
KWIP=3
36
214
V=J CALC RY
DNAY = RY-Ȳ
300
PUNCH J, I, M, FACTR DNAX, DNAY
XXI

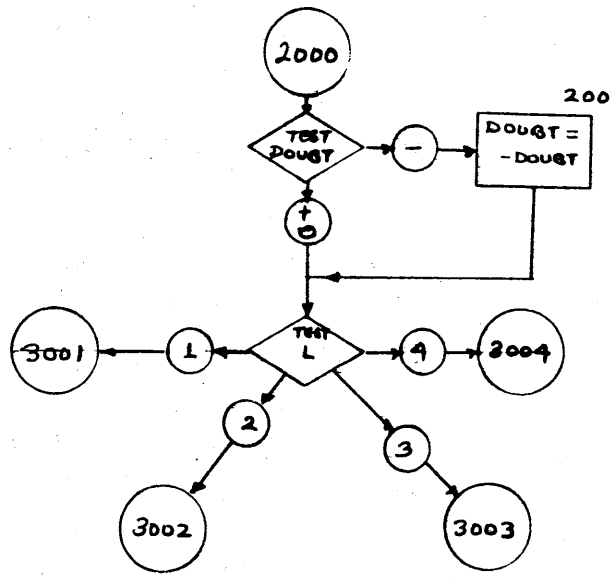

XXI
CALC ADx² ADy² SMRIX SMRIY
302
212
M=4
3
TEST M
1,2
I=NI
≠
I=I+1
XXA
4
=
XXB
J=J+1
≠
J=NJ
=
CALC ADX² ADY² FOR SECTION 1 SMRIY SMRIX
TYPE ADX² ADY² SMRIY SMRIX
320
CALC ADX² ADY² SECTION 3 SMRIY SMRIX
2
TEST KK
TYPE ADX² ADY² SMRIX SMRIY
322


322
TEST KR
2
330
ADX², ADY²
SECTION 2
SMRIY
SMRIX
TYPE
ADX²
ADY²
SMRIY
SMRIX
332
CALC
P/A
M/IY
M/IX
CALC
TSADY
TSBCY
TSDCX
TSABX
TYPE
OMIY OMIX
TSADY
TSBCY
TSDCX
TSABX
CALC
SA SB
SC SD
SST
TYPE
SA SB
SC SD
SST
XXV


XXV
TEST SB
−
501
DBYI = 0
DOUBT =
DX·SB /
(SA-SB)
L = 1
2000
+
0
503
DBXI = 0
DOUBT =
DY·SB /
(SB-SC)
L = 2
2000
3001
DBXI =
DOUBT
505
3002
DBYI =
DOUBT
505


505
TEST SD
−
+ 0
509
DDYI = 0
DOUBT = DY·SD / (SD−SC)
L = 4
2000
DDXI = 0
DOUBT = DY·SD / (SD−SC)
L = 3
2000
3003
DDYI = DOUBT
3004
DDXI = DOUBT
511
TYPE DBXI DBYI DDXI DDYI
XXVI


XXVI
HALT
SPACE
3


2000
TEST DOUBT
−
2001
DOUBT = −DOUBT
+ 0
TEST L
1
3001
2
3002
3
3003
4
3004

260000800009

```
      DIMENSION AC(3)
3300  FORMAT (2H  )
1001  FORMAT (F6.2,F6.2,F6.2,F6.2,F5.2,F12.2,F12.2,F12.2,I3,I3)
1005  FORMAT (F9.3,2H  ,F9.3,2H  ,F9.3,2H  ,F9.3,2H  ,F10.3,2H  ,F10.3)
1007FORMAT (I3,2H  ,I3,2H  ,I3,2H  ,F6.2,2H  ,F7.2,2H  ,F7.2)
1008  FORMAT (F10.0,2H  ,F10.0,2H  ,F10.0,2H  ,F10.0,2H  ,F10.0)
C  READ IN COLUMN DATA
      READ 1001, DY, DX, CV, CBX, CBY, DXE, DYE
        READ 1001, DDY1, DDX1, DBY1, DBX1, AS, P, OMX, OMY, NI, NJ
        READ 1001, AN, ANM1
    3KK = 1
      KR = 1
      SUMA = 0.0
      SUMAX = 0.0
      SUMAY = 0.0
C  CALCULATE COORDINATES OF P1 AND P2
      YDIF = DY - DBY1 - DDY1
      XDIF = DX - DBX1 - DDX1
      IF (DDY1) 12,14,12
   12RPX1 = CV
      RPY1 = DDY1 + CV*YDIF/XDIF
      GO TO 16
   14RPY1 = CV
      RPX1 = DDX1 + CV*XDIF/YDIF
   16IF (DBY1) 18,20,18
   18RPX2 = DX- CV
      RPY2 = DY - DBY1 - CV*YDIF/XDIF
      GO TO 22
   20RPX2 = DX - DBX1 - CV*XDIF/YDIF
      RPY2 = DY - CV
   22  PUNCH 1005, RPX1, RPY1, RPX2, RPY2
C  CALCULATE AREA OF STEEL AND MOMENT OF STEEL AREA (AY,AX)
      DO 697 J = 1,NJ
      IF (J-1) 26,28,26
   26IF (J-NJ) 30,32,30
   30M = 3
      I = 1
```

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```
        GO TO 35
   32M = 2
      GO TO 34
   28M = 1
   34DO 612 I = 1,NI
   35  KWIP = 4
   36V = I
      RX = CV + (V-1.0)*CBX
      V = J
      RY = CV + (V-1.0)*CBY
C  TEST IF BAR IS IN COMPRESSION OR TENSION AND SET FACTOR
      GO TO (48,68,58,38),M
   38IF (RY - RPY2) 40,42,42
   40FACTR = ANM1
```



```
        GO TO 80
   42FACTR = AN
        GO TO 80
   48IF (RX - RPX1) 50,52,52
   50FACTR = AN
        GO TO 80
   52FACTR = ANM1
        GO TO 80
   58IF (RY - RPY1) 60,62,62
   60FACTR = ANM1
        GO TO 80
   62FACTR = AN
        GO TO 80
   68IF (RX - RPX2) 70,72,72
   70FACTR = AN
      GO TO 80
   72FACTR = ANM1
   80   GO TO (30),214,214,81),KWIP
   81   PUNCH 1007, J, I, M, FACTR, RX, RY
        ACC = AS*FACTR
      SUMA = SUMA + ACC
      SUMAX = SUMAX + ACC*RX
      SUMAY = SUMAY + ACC*RY
      GO TO (612,612,90,697),M
   90M = 4
      I = NI
        GO TO 35
  612CONTINUE
  697CONTINUE
C  CALCULATE AREA AND MOMENTS OF AREA FOR CONCRETE
      PRINT 1008, SUMA, SUMAX, SUMAY
      SMRIY = 0.0
      SMRIX = 0.
      IF (DDY1) 102,104,102
  102AC(3) = DX*DDY1
      SUMA = SUMA + AC(3)
      SUMAX = SUMAX + AC(3)*DX/2.0
      SUMAY = SUMAY + AC(3)*DDY1/2.0
        SMRIY = AC(3)*DX**2/12.0 + SMRIY
        SMRIX = AC(3)*DDY1**2/12.0 + SMRIX
      KK = 2
      PRINT 1008, AC(3), SUMAY, SUMAX, SMRIY, SMRIX
  104IF (DBX1) 108,110,108
  108AC(2) = DBX1*(DY - DDY1)
      SUMA = SUMA + AC(2)
      SUMAY = SUMAY + AC(2)*(DY + DDY1)/2.0
      SUMAX = SUMAX   + AC(2)*(DX - DBX1/2.0)
        SMRIY = SMRIY + AC(2)*(DBX1**2)/12.0
        SMRIX = SMRIX + AC(2)*(DY-DDY1)**2/12.0
      KR = 2
      PRINT 1008, AC(2), SUMAY, SUMAX, SMRIY, SMRIX
  110SX = DX - DDX1 - DBX1
      SY = DY - DDY1 - DBY1
      AC(1) = SX*SY/2.0
      SUMA = SUMA + AC(1)
      SUMAX = SUMAX + AC(1)*(DDX1 + 2.0*SX/3.0)
      SUMAY = SUMAY + AC(1)*(DDY1 + SY/3.0)
        SMRIY = SMRIY + AC(1)*SX**2/18.0
        SMRIX = SMRIX + AC(1)*SY**2/18.0
      PRINT 1008, AC(1), SUMAY, SUMAX, SMRIY, SMRIX
      XBAR = SUMAX/SUMA
      YBAR = SUMAY/SUMA
      OMYR = OMY - P*(XBAR - DXE)
      OMXR = OMX - P*(DYE - YBAR)
        PRINT 1005, XBAR, YBAR
        PRINT 1008, SUMA, OMYR, OMXR
```

```
C  CALCULATE DISTANCE TO THE NEUTRAL AXIS OF STEEL
C  AND OBTAIN THE FACTOR
      DO 967 J = 1,NJ
      IF (J-1) 202,206,202
  202IF (J-NJ) 208,204,208
  204DNAY = DY - YBAR - CV
      M = 2
      GO TO 210
  206DNAY = YBAR -CV
      M = 1
  210DO 912 I = 1,NI
      V = I
      RX = CV + (V-1.0)*CBX
      DNAX = RX - XBAR
        KWIP = 1
        GO TO 36
  212DNAX = DX - XBAR - CV
        KWIP = 2
        GO TO 36
  208M = 3
      DNAX = XBAR - CV
        KWIP = 3
        GO TO 36
  214V = J
      RY = CV + (V-1.0)*CBY
      DNAY = RY - YBAR
  300 PUNCH 1007, J, I, M, FACTR, DNAX, DNAY
C  CALCULATE MOMENT OF INERTIA FOR STEEL ABOUT X AND Y AXIS
      ARKY = AS*(FACTR*(DNAX*DNAX))
      ARKX = AS*(FACTR*(DNAY*DNAY))
      SMRIY = SMRIY + ARKY
      SMRIX = SMRIX + ARKX
      GO TO (912,912,302,967),M
  302M = 4
      GO TO 212
  912CONTINUE
  967CONTINUE
      PRINT 1008, SMRIY, SMRIX
C  CALCULATE AD SQD FOR CONCRETE
      ARKY = AC(1)*(DDX1 + 2.0*SX/3.0 - XBAR)**2
      SMRIY = SMRIY + ARKY
      ARKX = AC(1)*(DDY1 + SY/3.0 - YBAR)**2
      SMRIX = SMRIX + ARKX
      PRINT 1008, ARKY, ARKX, SMRIY, SMRIX
      GO TO (322,320),KK
  320ARKY = AC(3)*(DX/2.0 - XBAR)**2
      SMRIY = SMRIY + ARKY
      ARKX = AC(3)*(YBAR-DDY1/2.0)**2

      SMRIX = SMRIX + ARKX
      PRINT 1008, ARKY, ARKX, SMRIY, SMRIX
  322GO TO (332,330),KR
  330ARKY = AC(2)*(DX - XBAR - DBX1/2.0)**2
      SMRIY = SMRIY + ARKY
      ARKX = AC(2)*(DY - YBAR - (DY-DDY1)/2.0)**2
      SMRIX = SMRIX + ARKX
      PRINT 1008, ARKY, ARKX, SMRIY, SMRIX
C  CALCULATE CONCRETE AND STEEL STRESS
  332POA = (-P/SUMA)
      OMIY = OMYR/SMRIY
      OMIX = OMXR/SMRIX
      TSADY = OMIY*XBAR
      TSBCY = (-OMIY*(DX - XBAR))
      TSDCX = (-OMIX*YBAR)
      TSABX = OMIX*(DY - YBAR)
        PRINT 1005, OMIY, OMIX, TSADY, TSBCY, TSDCX, TSABX
```



```
      SA = POA + TSADY + TSABX
      SB = POA + TSBCY + TSABX
      SC = POA + TSBCY + TSDCX
      SD = POA + TSADY + TSDCX
      SST = ((OMIY*(XBAR-CV))*AS + POA + AS*(OMIX*(DY-YBAR-CV)))*10.0
        PRINT 1005, SA, SB, SC, SD, SST
      IF (SB) 501,503,503
  501DBY1 = 0.0
        DOUBT = DX*SB/(SA-SB)
        L = 1
        GO TO 2000
 3001   DBX1 = DOUBT
      GO TO 505
  503DBX1 = 0.0
        DOUBT = DY*SB/(SB-SC)
        L = 2
        GO TO 2000
 3002   DBY1 = DOUBT
  505IF (SD) 507,509,509
  507DDX1 = 0.0
        DOUBT = DY*SD/(SA-SD)
        L = 3
        GO TO 2000
 3003   DDY1 = DOUBT
      GO TO 511
  509DDY1 = 0.
        DOUBT = DY*SD/(SD-SC)
        L = 4
        GO TO 2000
 3004   DDX1 = DOUBT
  511   PRINT 1005, DDY1, DDX1, DBY1, DBX1
        PAUSE
        PRINT 3300
        GO TO 3
 2000   IF (DOUBT) 2001,2002,2002
 2001   DOUBT = DOUBT*(-1.0)
 2002   GO TO (3001,3002,3003,3004),L
      END
```

```
260000800009
ENTER SOURCE PROGRAM, PUSH START
T7358 2002  GO TO (3001,3002,3003,3004),L
T7442       END

PROG SW 1 ONFOR SYMBOL TABLE, PUSH START
T9999 SIN
T9989 SINF
T9979 COS
T9969 COSF
T9959 ATAN
T9949 ATANF
T9939 EXP
T9929 EXPF
T9919 LOG
T9909 LOGF
T9899 SQRT
T9889 SQRTF
T9879 AC        T9859
T9849 3300
T[illegible]39 3300
T[illegible]29 T001
T9819 T001
T9809 T005
T9799 T005
T9789 T007
T9779 T007
T9769 T008
T9759 T008
T9749 DY
T9739 DX
T9729 CV
T9719 CBX
T9709 CBY
T9699 DXE
T9689 DYE
T9679 DDY1
T9669 DDX1
T9659 DBY1
T9649 DBX1
T9639 AS
T9629 P
T9619 OMX
T9609 OMY
T9599 NI
T9589 NJ
T[illegible]79 AN
T9569 ANM1
T9559 0003
T9549 KK
T9539 000T
T9529 KR
T9519 SUMA
T9509 0000000099
```



```
T9499 SUMAX
T9489 SUMAY
T9479 YDIF
T9469 000
T9459 XDIF
T9449 0012
T9439 0014
T[illegible]29 RPX1
T[illegible]19 RPY1
T9409 0016
T9399 0018
T9389 0020
T9379 RPX2
T9369 RPY2
T9359 001
T9349 0022
T9339 0697
T9329 J
T9319 0026
T9309 0028
T9299 0030
T9289 0032
T9279 M
T9269 0003
T9259 I
T9249 0035
T9239 0002
T9229 0034
T9219 0612
T9209 KWIP
T9199 0004
T9189 0036
T[illegible]79 V
T[illegible]9 RX
T9159 T000000001
T9149 RY
T9139 0048
T9129 0068
T9119 0058
T9109 0038
T9099 0040
T9089 0042
T9079 FACTR
T9069 0080
T9059 0050
T9049 0052
T9039 0060
T9029 0062
T9019 0070
T9009 0072
T8999 0300
T8989 0214
T8979 0081
T8969 ACC
T8959 0090
T8949 SMRIY
T8939 SMRIX
T8929 0102
T[illegible]9 0104
T8909 2000000001
T8899 T200000002


T8889 0108
T8879 0110
```

7

```
T8869 SX
T8859 SY
T8849 3000000001
T8839 T800000002

T8829 XBAR
T8819 YBAR
T8809 OMYR
T8799 OMXR
T8789 0967
T8779 0202
T8769 0206
T8759 0208
T8749 0204
T8739 DNAY
T8729 0210
T8719 0912
T8709 DNAX
T8699 0212
T8689 ARKY
T8679 002
T8669 ARKX
T8659 0302
T8649 0322
T8639 0320
T8629 0332
T8619 0330
T8609 003
T8599 POA
T8589 OMIY
T8579 OMIX
T8569 TSADY
T8559 TSBCY
T8549 TSBCX
T8539 TSABX
T8529 SA
T8519 SB
T8509 SC
T8499 SD
T8489 SST
T8479 006
T8469 T000000002
T8459 0501
T8449 0503
T8439 DOUBT
T8429 L
T8419 2000
T8409 3001
T8399 0505
T8389 3002
T8379 0507
T8369 0509
T8359 3003
T8349 0511
T8339 3004
T8329 2001
T8319 2002

SW 1 OFF TO IGNORE SUBROUTINES, PUSH START

PROCESSING COMPLETE
```


APPENDIX D

```
ENTER SOURCE PROGRAM, PUSH START
08000          READ 1003, NI, NJ
08036     1    READ 1005, RPX1, RPY1, RPX2, RPY2
08096          PRINT 1005, RPX1, RPY1, RPX2, RPY2
08156          PRINT 1001
08180          PRINT 1002
08204          PRINT 1001
08228          KUK = 2*NI + 2*(NJ-2)
08324          DO 77 N = 1,KUK
08336          READ 1003, J, I, M, FACTR, RX, RY
08420    77    PRINT 1003, J, I, M, FACTR, RX, RY
08540          PRINT 1001
08564          PRINT 1004
08588          PRINT 1001
08612          DO 88 N = 1,KUK
08624          READ 1003, J, I, M, FACTR, DNAX, DNAY
08708    88    PRINT 1003, J, I, M, FACTR, DNAX, DNAY
08828          PAUSE
08840          GO TO 1
08848 1001     FORMAT (2H  )
08876 1002     FORMAT (5H J    ,5H I    ,5H M    ,8HFACTOR   ,9H RX       ,7H R
Y    )
09014 1003     FORMAT (I3,2H  ,I3,2H  ,I3,2H  ,F6.2,2H  ,F7.2,2H  ,F7.2)
09116 1004     FORMAT (5H J    ,5H I    ,5H M    ,8HFACTOR   ,9H DNAX     ,7H D
NAY  )
09254 1005     FORMAT (F9.3,2H  ,F9.3,2H  ,F9.3,2H  ,F9.3,2H  ,F9.3)
09340          END

PROG SW 1 ONFOR SYMBOL TABLE, PUSH START
T9999 SIN
T9989 SINF
T9979 COS
T9969 COSF
T9959 ATAN
T9949 ATANF
T9939 EXP
T9929 EXPF
T9919 LOG
T9909 LOGF
T9899 SQRT
T9889 SQRTF
T9879 T003
T9869 T003
T9859 NI
T9849 NJ
T9839 0001
T9829 T005
```

T9819 T005
T9809 RPX1
T9799 RPY1
T9789 RPX2
T9779 RPY2
T9769 T001
T9759 T001
T9749 T002
T9739 T002
T9729 KUK
T9719 0002
T9709 000
T9699 002
T9689 0077
T9679 N
T9669 J
T9659 I
T9649 M
T9639 FACTR
T9629 RX
T9619 RY
T9609 T004
T9599 T004
T9589 0088
T9579 DNAX
T9569 DNAY

SW 1 OFF TO IGNORE SUBROUTINES, PUSH START

PROCESSING COMPLETE

APPENDIX E TEST #1

7200 7200 350 600 600 3600 3600

1020 000 1000 000 156 113200000 4536000000 3070800000 12 12

1000 900

Col. [illegible]
Test No 1
Dec 8, 61

ENTER SUBROUTINES, PUSH START
1620 FORTRAN SUBR. AUTO DIV 9/30/61
LOAD DATA

EXAMPLE 1

1ST ITERATION						
	+650.	+23280.	+24394.			
	+734.	+28139.	+49719.	+317260.	+6367.	
	+1864.	+79359.	+139229.	+854323.	+284350.	
	+42.843	+24.420				
	+3249.	+22961136.	+32252003.			
	+1352617.	+852102.				
	+49583.	+17303.	+1402201.	+869406.		
	+34394.	+274138.	+1436596.	+1143544.		
	+15.983	+28.203	+684.768	-466.008	-688.744	+1341.910
	+1678.341	+527.564	-1503.090	-352.313	+25720.226	
	+12.491	+.000	+18.705	+.000		
2ND	+653.	+23497.	+24564.			
	+899.	+30182.	+55876.	+388545.	+11695.	
	+1468.	+68509.	+126383.	+811586.	+147556.	
	+41.821	+22.670				
	+3021.	+24117723.	+30271212.			
	+1303112.	+749615.				
	+56067.	+17200.	+1359180.	+766816.		
	+30484.	+242636.	+1389664.	+1009453.		
	+17.355	+29.987	+725.820	-523.744	-679.842	+1479.274
	+1830.501	+580.936	-1578.180	-328.615	+28068.623	
	+10.958	+.000	+19.372	+.000		
3RD	+653.	+23497.	+24564.			
	+788.	+28887.	+51901.	+340847.	+7895.	
	+1500.	+66161.	+123905.	+772874.	+152598.	
	+42.105	+22.483				
	+2942.	+23796303.	+30058965.			
	+1266714.	+758265.				
	+52116.	+8389.	+1318831.	+766655.		
	+29413.	+228128.	+1348245.	+994783.		
	+17.649	+30.216	+743.159	-527.628	-679.364	+1496.228
	+1854.711	+583.923	-1591.670	-320.882	+28474.175	
	+10.619	+.000	+19.324	+.000		

TEST 2

7200	7200	350	600	600	3600	3600			
000	1000	000	1000	156	113200000	4536000000	3070800000	12	12
1000	900								

Col. Cin.
TEST NO 2
Dec 8, 61

4908000

EXAMPLE 2

1ST ITERATION

	+652.	+23098.	+24212.			
	+720.	+50132.	+71338.	+6000.	+311040.	
	+1872.	+95060.	+154954.	+287216.	+850176.	
	+47.765	+29.302				
	+3244.	+17389533.	+37778815.			
	+855191.	+1350632.				
	+17975.	+52640.	+873167.	+1403273.		
	+266377.	+32293.	+1139544.	+1435566.		
	+15.260	+26.316	+728.903	-369.821	-771.142	+1123.631
	+1503.592	+404.867	-1489.907	-391.182	+23140.053	
	+14.864	+.000	+15.384	+.000		
	+650.	+23383.	+24460.			
2ND	+1070.	+32414.	+61912.	+462349.	+19706.	
	+1503.	+75673.	+134057.	+895220.	+165259.	
	+41.583	+23.473				
	+3223.	+24387082.	+31180010.			
	+1381494.	+751065.				
	+61875.	+42347.	+1443369.	+793413.		
	+33369.	+275397.	+1476739.	+1068810.		
	+16.514	+29.172	+686.721	-502.296	-684.783	+1415.644
	+1751.227	+562.209	-1538.218	-349.200	+26791.033	
	+11.970	+.000	+19.271	+.000		
3RD	+653.	+23497.	+24564.			
	+861.	+29722.	+54524.	+372319.	+10290.	
	+1467.	+67221.	+124953.	+794898.	+145706.	
	+41.891	+22.536				
	+2982.	+24038494.	+30119178.			
	+1286985.	+750346.				
	+54744.	+13380.	+1341729.	+763726.		
	+29917.	+236100.	+1371647.	+999826.		
	+17.525	+30.124	+734.165	-527.654	-678.894	+1490.062
	+1844.715	+582.895	-1586.061	-324.241	+28301.151	
	+10.763	+.000	+19.349	+.000		
4TH	+653.	+23497.	+24564.			
	+774.	+28735.	+51396.	+334785.	+7481.	
	+1507.	+66019.	+123776.	+769069.	+154464.	
	+42.150	+22.482				
	+2936.	+23745465.	+30057879.			
	+1263286.	+760150.				
	+51593.	+7589.	+1314879.	+767740.		
	+29317.	+226621.	+1344197.	+994362.		
	+17.665	+30.228	+744.598	-527.293	-679.599	+1496.837
	1855.947	+584.056	-1592.380	-320.489	+28496.534	
	+10.602	+.000	+19.321	+.000		

TEST 2

ENTER SUBROUTINES, PUSH START
1620 FORTRAN SUBR. AUTO DIV 9/30/61
LOAD DATA

+12.527 +3.500 +59.472 +68.500

1ST ITERATION

J	I	M	FACTOR	RX	RY
+1	+1	+1	+10.00	+3.50	+3.50
+1	+2	+1	+10.00	+9.50	+3.50
+1	+3	+1	+9.00	+15.50	+3.50
+1	+4	+1	+9.00	+21.50	+3.50
+1	+5	+1	+9.00	+27.50	+3.50
+1	+6	+1	+9.00	+33.50	+3.50
+1	+7	+1	+9.00	+39.50	+3.50
+1	+8	+1	+9.00	+45.50	+3.50
+1	+9	+1	+9.00	+51.50	+3.50
+1	+10	+1	+9.00	+57.50	+3.50
+1	+11	+1	+9.00	+63.50	+3.50
+1	+12	+1	+9.00	+69.50	+3.50
+2	+1	+3	+10.00	+3.50	+9.50
+2	+12	+4	+9.00	+69.50	+9.50
+3	+1	+3	+10.00	+3.50	+15.50
+3	+12	+4	+9.00	+69.50	+15.50
+4	+1	+3	+10.00	+3.50	+21.50
+4	+12	+4	+9.00	+69.50	+21.50
+5	+1	+3	+10.00	+3.50	+27.50
+5	+12	+4	+9.00	+69.50	+27.50
+6	+1	+3	+10.00	+3.50	+33.50
+6	+12	+4	+9.00	+69.50	+33.50
+7	+1	+3	+10.00	+3.50	+39.50
+7	+12	+4	+9.00	+69.50	+39.50
+8	+1	+3	+10.00	+3.50	+45.50
+8	+12	+4	+9.00	+69.50	+45.50
+9	+1	+3	+10.00	+3.50	+51.50
+9	+12	+4	+9.00	+69.50	+51.50
+10	+1	+3	+10.00	+3.50	+57.50
+10	+12	+4	+9.00	+69.50	+57.50
+11	+1	+3	+10.00	+3.50	+63.50
+11	+12	+4	+9.00	+69.50	+63.50
+12	+1	+2	+10.00	+3.50	+69.50
+12	+2	+2	+10.00	+9.50	+69.50
+12	+3	+2	+10.00	+15.50	+69.50
+12	+4	+2	+10.00	+21.50	+69.50
+12	+5	+2	+10.00	+27.50	+69.50
+12	+6	+2	+10.00	+33.50	+69.50
+12	+7	+2	+10.00	+39.50	+69.50
+12	+8	+2	+10.00	+45.50	+69.50
+12	+9	+2	+10.00	+51.50	+69.50
+12	+10	+2	+10.00	+57.50	+69.50
+12	+11	+2	+9.00	+63.50	+69.50
+12	+12	+2	+9.00	+69.50	+69.50

J	I	M	FACTOR	DNAX	DNAY
+1	+1	+1	+10.00	-44.26	+25.80
+1	+2	+1	+10.00	-38.26	+25.80
+1	+3	+1	+9.00	-32.26	+25.80
+1	+4	+1	+9.00	-26.26	+25.80
+1	+5	+1	+9.00	-20.26	+25.80

+1	+6	+1	+9.00	-14.26	+25.80
+1	+7	+1	+9.00	-8.26	+25.80
+1	+8	+1	+9.00	-2.26	+25.80
+1	+9	+1	+9.00	+3.73	+25.80
+1	+10	+1	+9.00	+9.73	+25.80
+1	+11	+1	+9.00	+15.73	+25.80
+1	+12	+1	+9.00	+21.73	+25.80
+2	+13	+3	+10.00	+44.26	-19.80
+2	+13	+4	+9.00	+20.73	-19.80
+3	+13	+3	+10.00	+44.26	-13.80
+3	+13	+4	+9.00	+20.73	-13.80
+4	+13	+3	+10.00	+44.26	-7.80
+4	+13	+4	+9.00	+20.73	-7.80
+5	+13	+3	+10.00	+44.26	-1.80
+5	+13	+4	+9.00	+20.73	-1.80
+6	+13	+3	+10.00	+44.26	+4.19
+6	+13	+4	+9.00	+20.73	+4.19
+7	+13	+3	+10.00	+44.26	+10.19
+7	+13	+4	+9.00	+20.73	+10.19
+8	+13	+3	+10.00	+44.26	+16.19
+8	+13	+4	+9.00	+20.73	+16.19
+9	+13	+3	+10.00	+44.26	+22.19
+9	+13	+4	+9.00	+20.73	+22.19
+10	+13	+3	+10.00	+44.26	+28.19
+10	+13	+4	+9.00	+20.73	+28.19
+11	+13	+3	+10.00	+44.26	+34.19
+11	+13	+4	+9.00	+20.73	+34.19
+12	+1	+2	+10.00	-44.26	+39.19
+12	+2	+2	+10.00	-38.26	+39.19
+12	+3	+2	+10.00	-32.26	+39.19
+12	+4	+2	+10.00	-26.26	+39.19
+12	+5	+2	+10.00	-20.26	+39.19
+12	+6	+2	+10.00	-14.26	+39.19
+12	+7	+2	+10.00	-8.26	+39.19
+12	+8	+2	+10.00	-2.26	+39.19
+12	+9	+2	+10.00	+3.73	+39.19
+12	+10	+2	+10.00	+9.73	+39.19
+12	+11	+2	+9.00	+15.73	+39.19
+12	+12	+2	+9.00	+21.73	+39.19

APPENDIX F

Symbol Table List

AC	Concrete areas (see fig.3)
DY	Column dimension in Y Direction (see fig.1)
DX	Column dimension in X Direction (see fig.1)
CV	Distance to ℄ of reinforcing steel from the column edge.
CBX	Bar spacing in X direction
CBY	Bar spacing in Y direction
DXE	Assumed distance to YY axis from column edge AD
DYE	Assumed distance to XX axis from column edge DC
DDY1	Assumed distance from D along AD to neutral axis (see fig.1)
DDX1	Assumed distance from D along DC to neutral axis
DBY1	Assumed distance from B along BC to neutral axis (see fig.1)
DBX1	Assumed distance from B along AB to neutral axis
AS	Area of steel reinforcing bar
NI	Number of reinforcing bars in X direction
NJ	Number of reinforcing bars in Y direction
AN	Ratio of flexural modulus of elasticity for reinforcing steel to flexural modulus of elasticity for concrete
ANM1	AN - 1.0
P	Axial Load
ØMX	Moment about axis XX
ØMY	Moment about axis YY
KK	Switch (2 if area 3 is present - see fig.3)
KR	Switch (2 if area 2 is present - see fig.3)
SUMA	Sum of transformed areas
SUMAX	Sum of transformed area moments about AD
SUMAY	Sum of transformed area moments about DC
YDIF	Distance in Y direction between points where neutral axis is assumed to cross the column edges
XDIF	Distance in X direction between points where neutral axis is assumed to cross the column edges
RPX1	Distance from AD in X direction to where neutral axis is assumed to cross steel row at point P1 (see fig.2)
RPY1	Distance from DC in Y direction to where neutral axis is assumed to cross steel row at point P1 (see fig.2)
RPX2	Same as RPX1 for point P2
RPY2	Same as RPY1 for point P2
J	Counter for number of rows
M	Switch 1 for row 1 2 for row NJ 3 for column 1, rows 2 - (NJ-1) 4 for column NI, rows 2- (NJ-1)
V	Temporary work area
RX	Distance in X direction from AD to bar (J,I)

RY	Distance in Y direction from DC to bar (J,I)
FACTR	Factor relating steel area to transformed steel area
ACC	Transformed steel area
I	Counter for number of columns
SMRIY	Moment of inertia about XX axis for the transformed section
SMRIX	Moment of inertia about YY axis for the transformed section
SX	X dimension of triangle area 1
SY	Y dimension of triangle area 1
XBAR	Distance to axis YY from AD
YBAR	Distance to axis XX from DC
ØMYR	Revised moment about YY
ØMYR	Revised moment about XX
DNAY	Distance in Y direction between axis XX and centroid of steel reinforcing bar.
DNAX	Distance in X direction between axis YY and centroid of steel reinforcing bar.
ARKY	Work area for A $(Dx)^2$ for concrete areas
ARKX	Work area for A $(Dy)^2$ for concrete areas
PØA	Concrete stress due to axial load
OMIY	Y Moment/Y Moment of Inertia
OMIX	X Moment/X Moment of Inertia
TSADY	Stress along AD due to Y Moment
TSBCY	Stress along BC due to Y Moment
TSABX	Stress Along AB due to X Moment
TSDCX	Stress along DC due to X Moment
SA	Combined concrete stress at A (see fig.1)
SB	Combined concrete stress at B (
SC	Combined concrete stress at C
SD	Combined concrete stress at D
SST	Steel stress for bar under maximum tensile stress (in corner D - see fig.1)
KWIP	Switch - used to control return to phase III
DOUBT	Work area used in computing neutral axis location
L	Switch - used to control return from subroutine in phase IV
KUK	Counter used in listing program

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