Part 7

Program code for basic subroutines,
all explained in detail, **without** sign conventions!!

'beam axis system' 'member axis system'

For axially loaded members. Part 4 page 15

Private Sub MEMBER()

For perpendicular loaded members.

The 'left' is the member end where the 'beam axis system' is placed.

Private Sub **BEAM1()** and 1 - 2
Private Sub QLOAD() 3

Private Sub **BEAM2()** 4 - 6

Private Sub **BEAM3()** and 7 - 8
Private Sub TWOEQUATIONS()

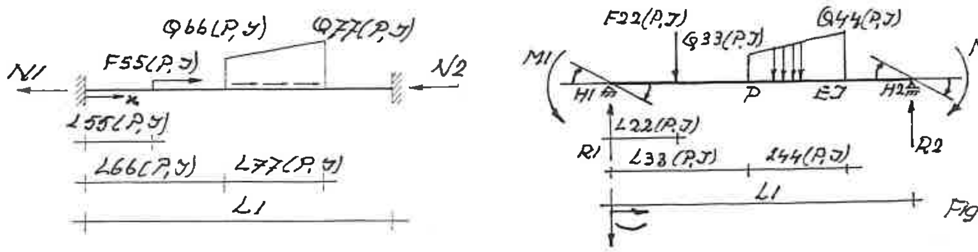


Fig. 1.

Private Sub T5M5XX() 9 -11
Calculation of shear force T5 at X m from the 'left'.

Private Sub T5M5X() 12-13
Calculation of shear force T5 and bending momemt M5 with distances to the 'left', after using BEAM1, BEAM2 or BEAM3.

Private Sub MMAXM5() 14
Calculation of the maximum moment and bending moment zero points. with distances from the 'left'. With T5M5XX.

Private Sub H8Z8XX() 15-17
Calculation of slope deflection H8 displacement Z8 at X m from the 'left'.

Private Sub ZMAXZ8() 18
Calculation of the largest displacement Z8 with distance X m from the 'left'. With H8Z8XX.

Private Sub T5M5G()   Private Sub T5M5() 19
Calculation of shear forces T5 and T7 at each G m from the 'left'.

Private Sub H8Z8G() 20
Calculation of slope deflection H8 and displacement Z8 each G m from the 'left'. With H8Z8XX.

Private Sub CONSTRMATCCCBEAM() 21

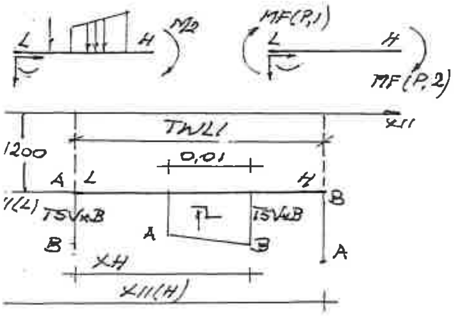
Private Sub FILLINGS5CBEAM() to fill CC. 22

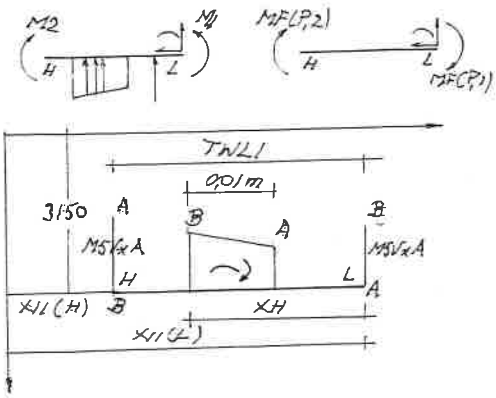
Private Sub MEMBERMATS5CBEAM() 22

Private Sub **CBEAMMAINCALC()** 23-29

Private Sub CBDRAWT5() 30
Drawing the shear force diagram.

Private Sub T5MAX()U 31
Determining the largest transverse force.





Private Sub CBDRAWM5() 32
Drawing the bending moment diagram.

Private Sub M5MAX() 32
Determining the largest bending moment.

Private Sub DRAWELCURVE() 33
Drawing the bending elstic curve.

Summary of the subroutines. 37-42

Private Sub BEAM1()

The statically determinate supported beam on two supports, a hinge support and a roller (hinge) support. The beam can be loaded with concentrated loads and uniformly distributed loads.

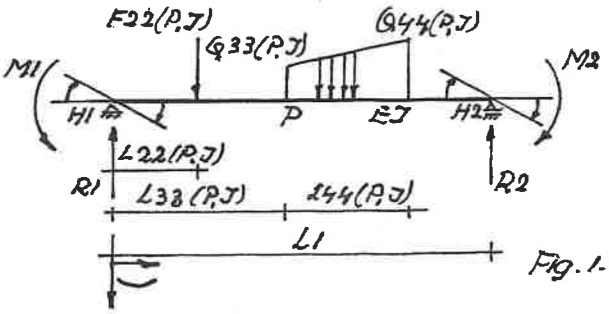


Fig.1.
The reactions R1 and R2 and the slopes H1 and H2 to be calculated are set zero first.
R1=0 : R2=0 : H1=0 : H2=0

The concentrated loads.

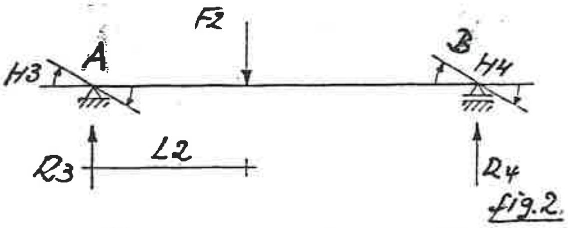


Fig.2.
For I=1 T NFB(P)
F2=F22(P,I) : L2=L22(P,I)

Σ mom.A =0
F2*L2-R4*l1=0 ⇒ R4=F2*L2/L1
Σ vert. =0
R3+R4-F2=0 ⇒ R3=F2-R4
These values are added to the preceding values of R1 and R2 with R1=R1+R3 : R2=R2+R4.

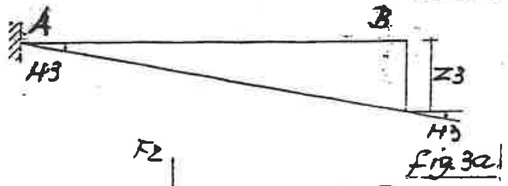


Fig.3a.
At the left beam end the unloaded beam is thought to be clamped under the assumed slope H3. The deflection, or displacement, of beam end B is
Z3=H3*L1.

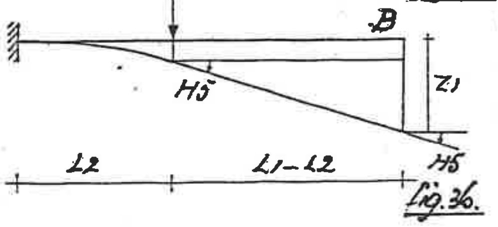


Fig.3b.
Next the unloaded beam is thought to be horizontally clamped at A and loaded with force F2 at distance L2 from A.
With bending stiffness EI and by means of the standard formulas (page 36) one finds slope H5 at beam end B which is equal to the slope at the place where F2 is applied,
H5=F2*L2^2/(2*EI)

and the displacement Z1 at B which is equal to the displacement at C plus the displacement at C due to the slope H5 at C,
Z1=F2*L2^3/(3*EI)+H5*(L1-L2).

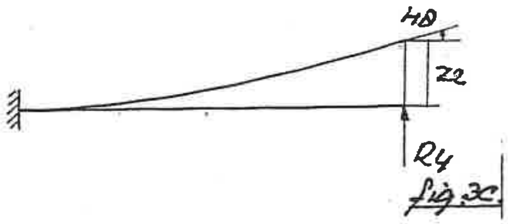


Fig.3c.
The on the left horizontally clamped beam now is loaded with reaction force R4 which causes displacement Z2 at B.
Z2=R4*L1^3/(3*EI)

The total displacement of B is zero.
Z3+Z1-Z2=0 or H3*L1=Z2-Z1 from which

H3=(Z2-Z1)/L1.

Slope H4 at beam end B, assumption to the right then becomes H4=H3+H5-H8.

Slope H4 at B, assumption turning to the right the becomes H4=H3+H5-H8.
The calculated slopes H3 and H4 due to F2 are added to the preceding valus of H1 and H2 with H1=H1+H3 : H2=H2+H4.
Then the next concentrated load with

Next I

```
Private Sub BEAM1()
'The statically determinate beam on
'two supports, the simple beam.
'Calculation of the support reac-
'tions and the slopes at the beam
'ends.
R1=0 : R2=0 : H1=0 : H2=0
'The concentrated loads.
For I= 1 To NFB(P)
F2=F22(P,I) : L2=L22(P,I)
R4=F2*L2/L1 : R3=F2-R4
R1=R1+R3 : R2=R2+R4
H5=F2*L2^2/(2*EI)
Z1=F2*L2^3/(3*EI)+H5*(L1-L2)
Z2=R4*L1^3/(3*EI)
H3=(Z2-Z1)/L1 : H8=R4*L1^2/(2*EI)
H4=H3+H5-H8
H1=H1+H3 : H2=H2+H4
Next I
```

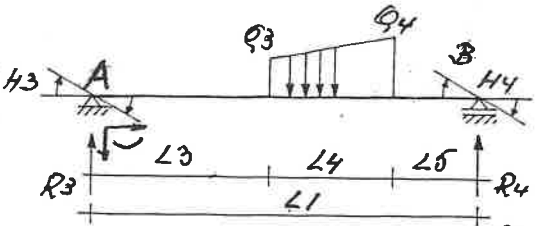


fig.4.

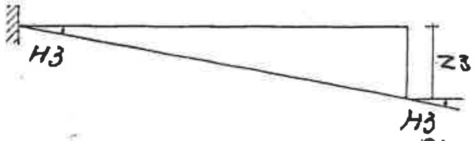


fig.5a

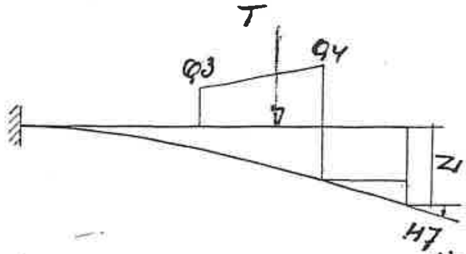


fig.5b.

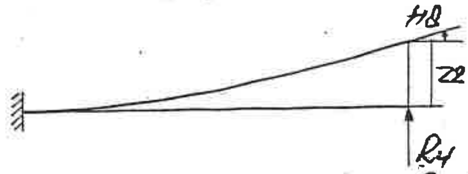


fig.5c.

```
'The distributed loads.
For I=1 to NQT(P)
Q3=Q33(P,I) : Q4=Q44(P,I)
L3=L33(P,I) : L4=L44(P,I)
L5=L1-L3-L4
QLOAD
R4=T*(L3+A1)/L1 : R3=T-R4
R1=R1+R3 : R2=R2+R4
Z2=R4*L1^3/(3*EI)
H3=(Z2-Z1)/L1 : H8=R4*L1^2/(2*EI)
H4=H3+H7-H8
H1=H1+H3 : H2=H2+H4
Next I
```

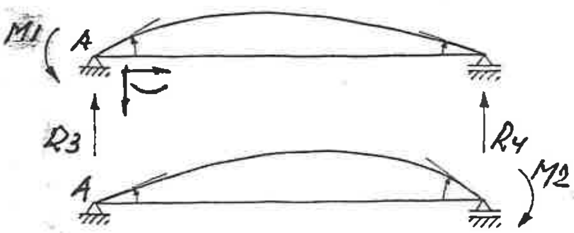


fig.6.

```
'The beam end moments M1 and M2.
R4=(M2-M1)/L1 : R3=-R4
R1=R1+R3 : R2=R2+R4
H3=-M1*L1/(3*EI)-M2*L1/(6*EI)
H4=M1*L1/(6*EI)+M2*L1/(3*EI)
H1=H1+H3 : H2=H2+H4
End Sub
```

The distributed loads.

Fig.4.
For I=1 To NQB(P)
Q3=Q33(P,I) : L3=L33(P,I)
Q4=Q44(P,I) : L4=L44(P,I)

Before subroutine QLOAD is called first length L5 has to be dterminated, see next page.

L5=L1-L3-L4

Then follows QLOAD with which for instance are calculated resultant T, length A1, slope H7 and displacement Z1 of fig.5b.

After that the reactions are calculated.

Σ mom.A =0
T*(L3+A1)-R4*L1=0 ⇒ R4=T*(L3+A1)/L1
Σ vert. =0
R3+R4-T=0 ⇒ R3=T-R4

And then R1=R1+R3 : R2=R2+R4.

And so on laike with the concentrated loads.

Fig.5a.
The displacement of B is Z3=H3*L1.
Fig.5b.
Subroutine QLOAD, next page, gives H7 and Z1.
Fig.5c.
Z2=R4*L1^3/(3*EI)
The total displacement of B is zero.
Z3+Z1-Z2=0 or H3*L1=Z2-Z1 from which
H3=(Z2-Z1)/L1.

Due to reaction R4 arises
H8=R4*L1^2/(2*EI) and the slope at B becomes
H4=H3+H7-H8.
Now H3 and H4 are known and follow
H1=H1+H3 : H2=H2+H4.
And then the next distributed load with
Next I.

The beam end moments M1 and M2.

Fig.6.
Σ mom.A =0
M2-M1-R4*L1=0 ⇒ R4=(M2-M1)/L1
Σ vert. =0
R3+R4=0 ⇒ R3=-R4
In the figures the deformations of the beams due to M1 and M2 are drawn. The magnitude of the slopes one can find with the formulas of page 36 .
The assumption for H3 and H4 are like that for H1, so to the right.

H3=-M1*L1/(3*EI)-M2*L1/(6*EI)
H4=M1*L1/(6*EI)+M2*L1/(3*EI)

Then H1=H1+H3 : H2=H2+H4 and the end of the subroutine with

End Sub

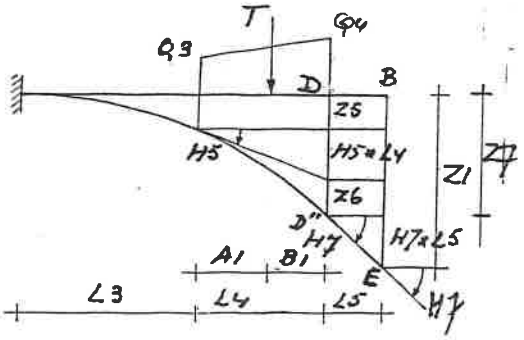


fig.1.

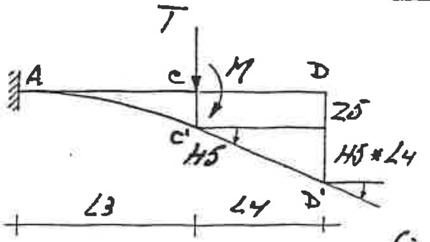


fig.2a.

```
Private Sub QLOAD()
'The statically determinate on the
'left clamped beam with trapeze
'like distributed load.

T=0.5*(Q3+Q4)*L4
B1=(2*Q3+Q4)*L4/(3*(Q3+Q4))
A1=L4-B1 : M=T*A1

Z5=T*L3^3/(3*EI)+M*L3^2/(2*EI)
H5=T*L3^2/(2*EI)+M*L3/EI
Z6=Q4*L4^4/(8*EI)
Z6=Z6-(Q4-Q3)*L4^4/(30*EI)
H6=Q4*L4^3/(6*EI)
H6=H6-(Q4-Q3)*L4^3/(24*EI)

H7=H5+H6 : Z7=Z5+H5*L4+Z6
Z1=Z7+H7*L5
End Sub
```

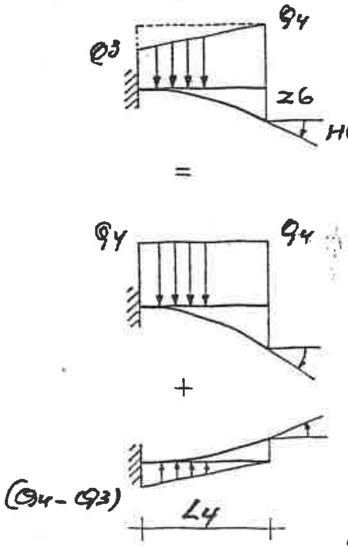


fig.2b

Private Sub QLOAD()

Calculation of displacement and slope at member end B of the on the left clamped horizontal beam due to a trapeziform distributed load.

Fig.1.
The beam is after being clamped not loaded, after that loaded with the distributed load.
T is the resultant, the area of the trapeze.
T=.5*(Q3+Q4)*L4

The centre of gravity of the trapeze lies at distance B1 from the right side of it and is
B1=(2*Q3+Q4)*L4/(3*(Q3+Q4)) Further is
A1=L4-B1.

Fig.2a.
First now the effect of the bending over part AC. Resultant T is resolved in a transverse force T at C and a bending moment M=T*A1 at C. Through that arise displacement Z5 and slope H5 at C'.

Z5=T*L3^3/(3*EI)+M*L3^2/(2*EI)
H5=T*L3^2/(2*EI)+M*L3/EI

C'D' is straight. D displaces over Z5 plus the effect of angle H5 at C', H5*L4.

Fig.2a and 2b.
Next the bending over part C'D'. The displacement of C and slope H5 at C' are fixed now. Unloaded part C'D' is clamped under slope H5 at C' after which the distributed load is applied. Then the deformation arises as drawn in fig.1. In fig. member part C'D' is drawn horizontally clamped which is allowed because displacement and slope are very small with respect to the length of the member.

By summing the effect of the triangular and trapeziform distributed loads arise Z6 and H6.

Z6=Q4*L4*4/(8*EI)-(Q4-Q3)*L4^4/(30*EI)
H6=Q4*L4^3/(6*EI)-(Q4-Q3)*L4^3/(24*EI)

From C' upto C'' (see fig.1) angle H5 increases with angle H6. Angle H7 at D'' then becomes
H7=H5+H6.

The displacement of D becomes
Z7=Z5+H5*L4+Z6.

The last part of the beam is not bent, is straight, so that at beam end E also angle H7 arises.

Due to slope H7 at D'' follows yet a displacement H7*L5 at B.

The total displacement of member end B becomes

Z1=Z7+H7*L5

and finally the end of the subroutine QLOAD,

End Sub

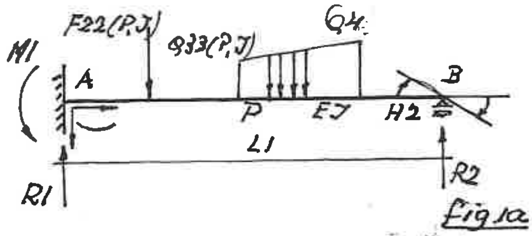


Fig.1a.

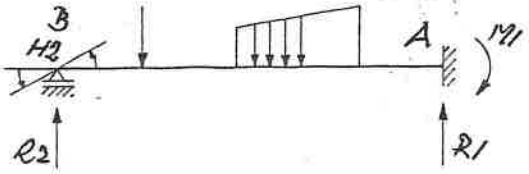


Fig.1b.

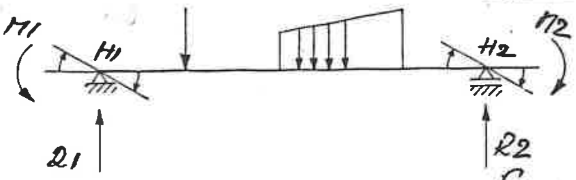


Fig.1c.

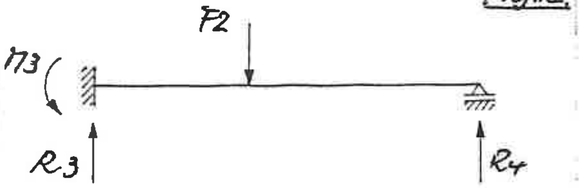


Fig.2a.

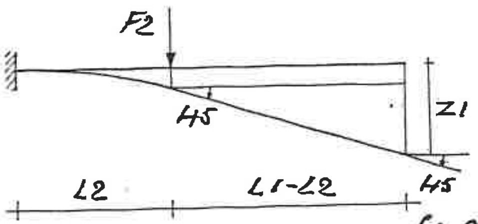


Fig.2b.

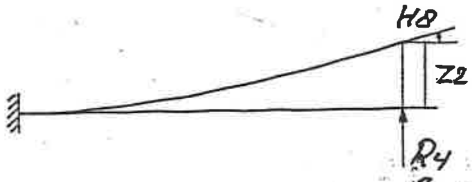


Fig.2c.

```
Private Sub BEAM2()
'The onefold statically indetermi-
'nate beam on two supports.
'Calculation of the reactions and
'the slope at the not clamped beam-
'end.
R1=0 : R2=0
H1=0 : H2=0
For I=1 To NFB(P)
F2=F22(P,I) : L2=L22(P,I)
If LE(P)=1 Then L2=L1-L2
H5=F2*L2^2/(2*EI)
Z1=F2*L2^3/(3*EI)+H5*(L1-L2)
R4=Z1*(3*EI)/(L1^3)
M3=F2*L2-R4*L1 : R3=F2-R4
R1=R1+R3 : R2=R2+R4 : M1=M1+M3
H8=R4*L1^2/(2*EI)
H4=H5-H8 : H2=H2+H4
Next I
```

Private Sub BEAM2()

The onefold statically indeterminate beam on two supports.

Fig.1a.
It is assumed that the beam is clamped on the left and sipprted bij a roller on the right.
The reactions R1 and R2, the clamp moment M1 and slope H2 at the support on the right.
At the member end on the right does not act a member end load moment.
Fig.1b.
If the beam is clamped on the right and supported by a roller on the left, then the calculation goes as for fig.1a for which the data put in for fig.1a are altered. After the calculation follows restoration of 'left and right'.
For example, moment M1 becomes M2. See fig.5 on the next page.

Fig.1c.
Here are shown the assumed directions of the reactions, member end momemnts and slopes.
First all unknowns are set zero.
R1=0 : R2=0 : M1=0 : M2=0 :H1=0 : H2=0

The concentrated loads.

Fig.2a, 2b, 2c.
For I=1 To NFB(P)
F2=F22(P,I) : L2=L22(P,I)
If LE(P)=1 then the hinge is on the left and is taken distance for force F2 from the right.
If LE(P)=1 Then L2=L1-L2

Due to F2 arise H5 and Z1.
H5=F2*L2^2/(2*EI)
Z1=F2*L2^3/(3*EI)+H5*(L1-L2)
Due to the (still unknown) reaction R4 arises
Z2=R4^L1^3/(3*EI).

The displacement of B is zero.
Z1-Z2=0 or Z1-R4*L1^3/(3*EI) from which
R4=Z1*(3*EI)/L1^3.

Fig.2a.
Σ mom.A =0
F2*L2-R4*L1-M3=0 ⇒ M3=F2*L2-R4*L1
Σ vert. =0
R3+R4-F2=0 ⇒ R3=F2-R4

R3, R4 and M3 are added to preceding values of R1, R2 and M1 with
R1=R1+R3 : R2=R2+R4 : M1=M1+M3.

Slope H8 due to R4 is
H8=R4*L1^2/(2*EI).

Due to F2 and R4 arises slope H4 at B.
H4=H5-H8

Finally H2=H2+H4 and then the next concentrated load F22(P,I) with

Next I.

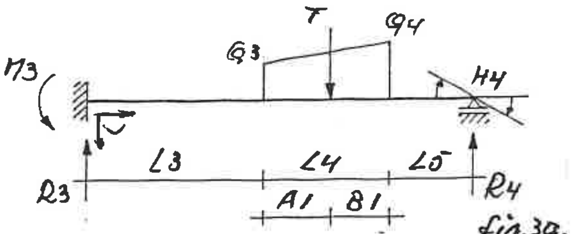


fig.3a.

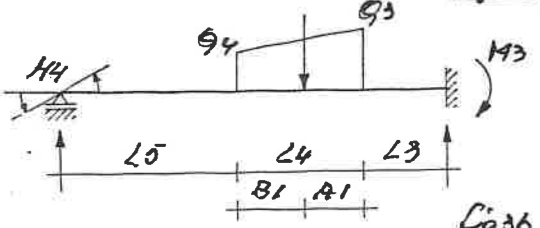


fig.3b.

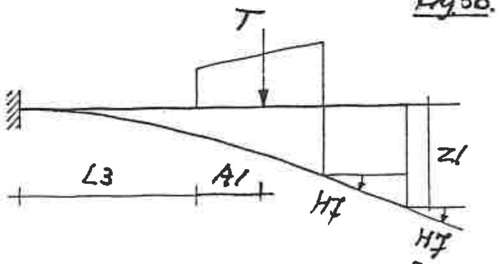


fig.4a

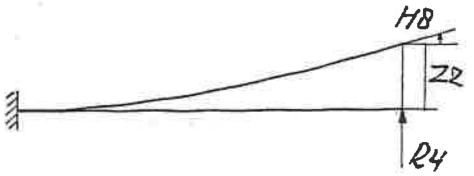


fig.4b.

```
'The distributed loads.
For I=1 To NQB(P)
Q3=Q33(P,I) : L3=L33(P,I)
Q4=Q44(P,I) : L4=L44(P,I)
L5=L1-L3-L4

If LE(P)=1 Then
Q3=Q4 : Q4=Q33(P,I) : L3=L1-L3-L4
L5=L1-L3-L4
End If

QLOAD
R4=Z1*(3*EI)/L1^3
M3=T*(L3+A1)-R4*L1 : R3=T-R4
R1=R1+R3 : R2=R2+R4 : M1=M1+M3
H8=R4*L1^2/(2*EI)
H4=H7-H8 : H2=H2+H4
Next I

If LE(P)=1 Then
R=R1 : R1=R2 : R2=R : M2=M1 : M1=0
H1=-H2 : H2=0
End If
```

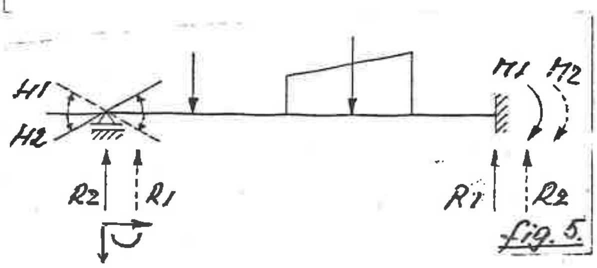


fig.5.

The distributed loads.

Fig.3a.
For I=1 To NQB(P)
Q3=Q33(P,I) : L3=L33(P,I)
Q4=Q44(P,I) : L4=L44(P,I)
Before calling subroutine QLOAD first becomes
L5=L1-L3-L4.

Fig.3b.
Is LE(P)=1 then the hinge is on the left and the clamp on the right. Then the data are changed in such way as if it is the construction of fig.3a. Just realize that data of fig.3b are put in exactly in the same way as for fig.3a.
If LE(P)=1 Then
Q3=Q44(P,I) : Q4=Q33(P,I) : L3=L1-L3-L4
L5=L1-L3-L4
End If

Fig.4a.
Subroutine QLOAD delivers T, A1, Z1 and H7.

Fig.4b.
Due to R4 arises Z2=R4*L1^3/(3*EI)
The displacement of B is zero.
Z1-Z2=0 or Z1-R4*L1^3/(3*EI) from which
R4=Z1*(3*EI)/L1^3

Fig.3a.
Σ mom.A =0
T*(L3+A1)-R4*L1-M3=0 ⇒ M3=T*(L3+A1)-R4*L1
Σ vert. =0
R3+R4-T=0 ⇒ R3=T-R4 en dan
R1=R1+R3 : R2=R2+R4 : M1=M1+M3.
Slope H8 due to R4 is
H8=R4*L1^2/(2*EI).
Slope H4, assumption nto the right, fig.3q for both construction cases then becomes
H4=H7-H8, and after that addition gives
H2=H2+H4 and then the next distributd load with

Next I.

If the clamp is on the left then the calculated R1, R2, M1 and M2 are correct. Further are M2=0 and H1=0 as was assumed in the beginning.

Fig.5.
If the hinge is on the left, the clamp on the right, then R2 is calculated on nthe left, R1 and M1 on the right. Also slope H2 on the left which is now to the left. For all members the names of the veriables on the left (place of beam axis system) are R1, M1 and H1, and on the right R2, M2 and H2.
To make the names suit the following lines are added.
If LE(P)=1 Then
R=R1 : R1=R2 : R2=R : M2=M1 : M1=0
H1=-H2 : H2=0
End If
R1 is kept for a while with R for make changes in a correct way. Because H2 is to the left becomes H1=-H2.

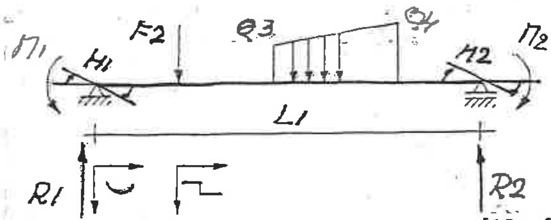


Fig.6.

Fig.6.
Again the beam with the assumed directions of the member end moments M1 and M2, the reactions R1 and R2, and the slope deflections H1 and H2.

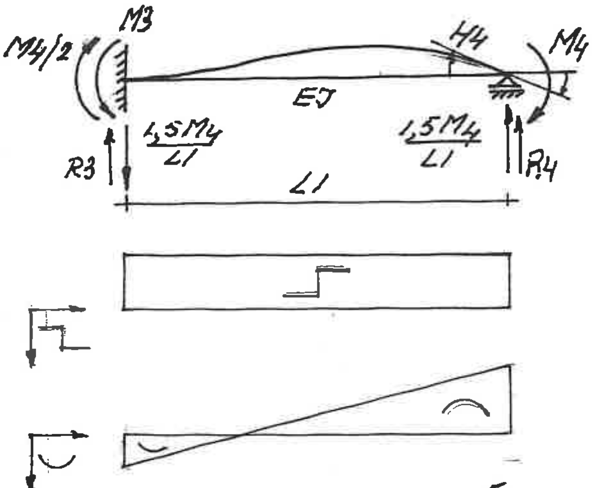


Fig.7a.

Fig.7a.
LE(P)=0.
The right beam end is loaded with momemnt M4, assumed to be directed to the right. Then the deformation caused bij this moment is drawn with which the real directtions of the rections can be drawn, the vertical ones with magnitude 1.5*M4/L1, on the left downward and on the right upward,
and the reaction moment M4/2 directed to the right, see the formulas on page 36 .
The reactions R1, R2 and M3.
Reaction R3 is assumed directed upward, opposite to the real direction of the reaction on the left, then becomes R3=-1.5*M4/L1.
Reaction R4 is assumed directed upward, the same like the real direction of the reaction on the right, so R4=1.5*M4/L1.
Reaction moment M3 is assumed to the left, the real direction of the reaction moment is to the right, so M3=-M4/2.
The slope deflection at the right member end is H4=M4*L1/(4*EI) to the right like the figure shows.
The results added to previous values gives
R1=R1+R3 : R2=R2+R4 : M1=M1+M3.
Moment M2 at the right end becomes M2=M4, and the slope deflection H2=H2+H4.

```
    If LE(P)=0 Then
    R3=-1.5*M4/L1 : R4=1.5*M4/L1
    M3=-M4/2 : H4=M4*L1/(4*EI)
    R1=R1+R3 : R2=R2+R4 : M1=M1+M3
    M2=M4 : H2=H2+H4

    ElseIf LE(P)=1 Then

    R3=1.5*M4/L1 : R4=-1.5*M4/L1
    M3=-M4/2 : H4=M4*L1/(4*EI)
    R1=R1+R3 : R2=R2+R4   : M2=M2+M3
    M1=M4 : H1=H1-H4
    End If

End Sub
```

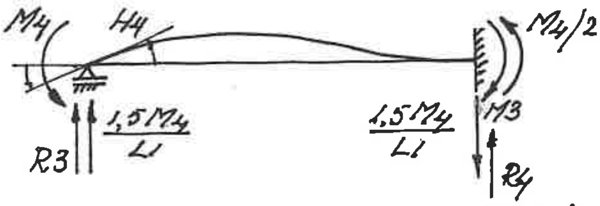


Fig.7b.

Fig.7b.
LE(P)=1.
Now with the hinge support on the left. The reactions are found in the same way. Taking into account the real directions of the reactions due to M4, and the assumed directions of R3, R4 and M3 follow
R3=1.5*M4/L1 : R3=-1.5*M4/L1 : M3=-M4/2 and H4=M4*L1/(4*EI).
Then again R1=R1+R3 : R2=R2+R4 and then instead of M1 now M2=M2+M3, and instead of M2 now M1=M4.
And instead of H2 now H1=H1-H4.

There is only one load moment, one can write as well, shorter,
R1=R1+1.5*M4/L1 : R2=R2-1.5*M4/L1 : M2=M2-M4/2
M1=M4
H1=H1-M4*L1/(4*EI).

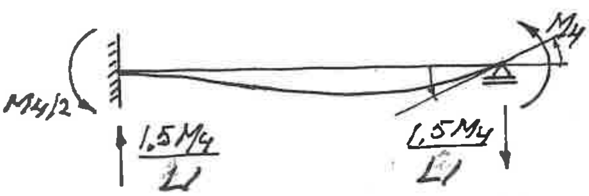


Fig.8.

Fig.8.
In fig.7a member end load moment M4 has an assumed direction to the right like that of M2. But that not necessary, one may assume the direction of moment M4 to the left, then the deformations caused by M4 is like drawn on the left with which follow the real directions of the reactions, on the left a vertical reaction upward and a momemnt to the left, and on the right a vertical reaction downward. Then follows, on the short way,
R1=R1+1.5*M4/L1 : R2=R2-1.5*M4/L1 : M1=M1+M4/2
M2=-M4
H2=H2-M4*L1/(4*EI).
And one can also assume for M4 of fig.7b a direction to the right instead of to the left.

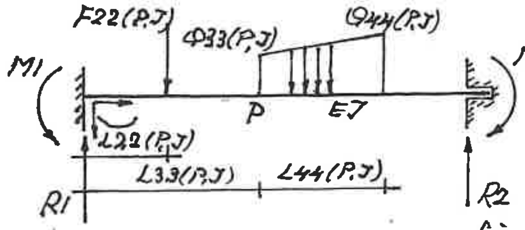


fig.1a.

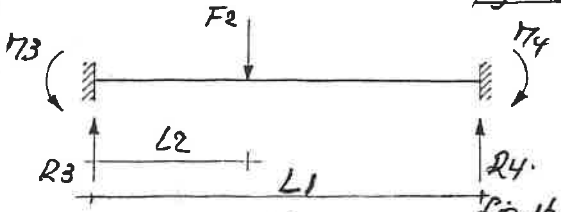


fig.1b.

```
Private Sub BEAM3()
'The twofold statically indtermi-
'nate beam on two supports
'Calculation of the reactions.
R1=0 : R2=0 : M1=0 : M2=0
H1=0 : H2=0
'The concentrated loads.
For I=1 To NFB(P)
F2=F22(P,I) : L2=L22(P,I)
H5=F2*L2^2/(2*EI)
Z1=F2*L2^3/(3*EI)+H5*(L1-L2)
A=L1^3/(3*EI) : B=-L1^2/(2*EI)
C=Z1
D=L1^2/(2*EI) : E=-L1/EI : F=H5
TWOEQUATIONS
M3=F2*L2-R4*L1+M4 : R3=F2-R4
R1=R1+R3 : R2=R2+R4
M1=M1+M3 : M2=M2+M4
Next I
```

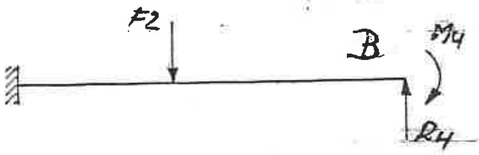


fig.2a.

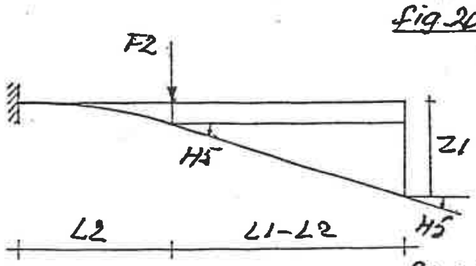


fig.2b.

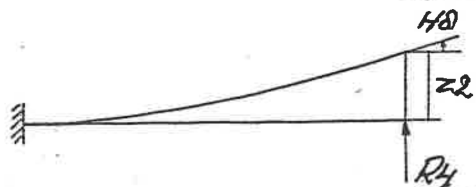


fig2c

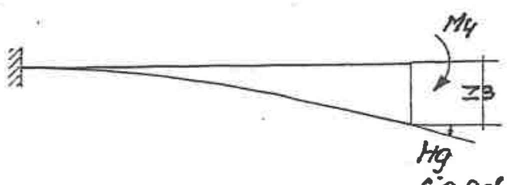


fig.2d.

Private Sub BEAM3()

The twofold statically indeterminate beam on two supports.

Fig.1a en ib.
For each load case the reactions R3, R4, M3 and M4 are calculated and added to preceding values of R1, R2, M1 and M2 which are made zero before.
Per belastinggeval worden de reacties R3, R4,
R1=0 : R2=0 : M1=0 : M2=0
At the clamps the slopes are zero
H1=0 : H2=0.

The concentrated loads.

Fig.2a.
For I=1 To NFB(P)
F2=F22(P,I) : L2=L22(P,I)

The beam is clamped on the left under a slope H1=0 and is loaded by member load force F2 and the reaction force R4 and reaction moment M4. Displacement and slope of B are zero. That gives two equations from which R4 and M4 are solved. This is done by solving x and y from two equations as given here below.

ax + by = c
dx + ey = f   Solution of x and y gives

x={c-b(cd-af)/(db-ae)}/a   and
y=(cd-af)/(db-ae)

That becomes subroutine TWOEQUATIONS, see next page at the bottom.

Fig.2b, 2c en 2d.
Due to F2 arises H5=F2*L2^2/(2*EI), then displacement Z1 becomes

Z1=F2*L2^3/(3*EI)+H5*(L1-L2).

Due to R4 arises Z2=R4*L1^3/(3*EI)
and due to M4   Z3=M4*L1^2/(2*EI).

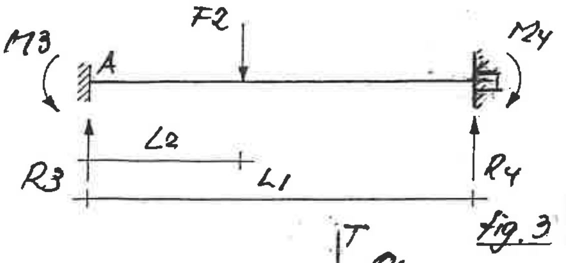
The displacement of B is zero.
Z1-Z2+Z3=0   or   Z2 - Z3 = Z1.
That becomes the equation A*R4 + B*M4 = C.
A, B and C then are
A=L1^3/(3*EI) : B=-L1^2/(2*EI) : C=Z1.

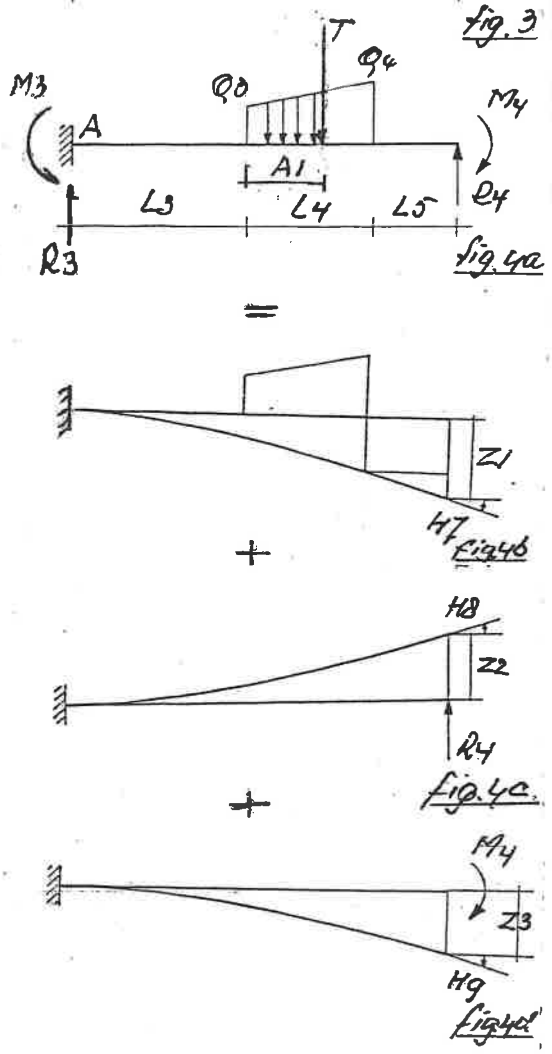
The slopes at the member end due to F2, R4 andM4 then are

H5=F2*L2^2/(2*EI),
H8=R4*L1^2/(2*EI) and
H9=M4*L1/EI.

The slope at B is zero.
H5-H8+H9=0   or   H8 - H9 = H5.
The second equation is   D*R4 + E*M4 = F.
D, E and F then are
D=L1^2/(2*EI) : E=-L1/EI : F=H5.

With subroutine TWOEQUATIONS the unknowns R4 and M4 are solved from the equations after which R3 and R4 can be calculated.






```
'The distributed loads.
For I=1 To NQB(P)
Q3=Q33(P,I)  : L3=L33(P,I)
Q4=Q44(P,I)  : L4=L44(P,I)
L5=L1-L3-L4
QLOAD
A=L1^3/(3*EI)  : B=-L1^2/(2*EI)
C=Z1
D=L1^2/(2*EI)  : E=-L1/EI  : F=H7
TWOEQUATIONS
M3=T*(L3+A1)-R4*L1+M4  : R3=T-R4
R1=R1+R3  : R2=R2+R4
M1=M1+M3  : M2=M2+M4
Next I
End Sub

Private Sub TWOEQUATIONS()
R4=(C-B*(C*D-A*F)/(D*B-A*E))/A
M4=(C*D-A*F)/(D*B-A*E)
End Sub
```

Fig.3.
Σ mom.A =0
F2*L2-R4*L1+M4-M3=0 ⇒ M3=F2*L2-R4*L1+M4
Σ vert. =0
R3+R4-F2=0 ⇒ R3=F2-R4

Now all four reactions are known follow
R1=R1+R3 : R2=R2+R4 : M1=M1+M3 : M2=M2+M4
and then the next concentrated load with
Next I.

The distributed loads.

Fig.4a, 4b, 4c en 4d.
For I=1 To NQB(P)
Q3=Q33(P,I) : L3=L33(P,I)
Q4=Q44(P,I) : L4=L44(P,I)

Before calling subroutine QLOAD page 33 first becomes L5=L1-L3-L4. Next follows QLOAD which calculates T, A1, Z1 and H7.

As for the concentrated loads follow the displacements due to R4 and M4.
Z2=R4*L1^3/(3*EI)
Z3=M4*L1^2/(2*EI)

The displacement of B is zero.

Z1-Z2+Z3=0 or	Z2	-	Z3	=	Z1.
The first equation is	A*R4	+	B*M4	=	C.
	ax	+	by	=	c

Then A, B and C become
en volgen voor A, B en C
A=L1^3/(3*EI) : B=-L1^2/(2*EI) : C=Z1.

The slopes at B are H7 due to the distributed load which was calculated with QLOAD, and H8 and H9 due to R4 and M4.
H8=R4*L1^2/(2*EI)
H9=M4*L1/EI
The slope at B is zero.

H7-H8+H9=0 or	H8	-	H9	=	H7.
The second equation is	D*R4	+	E*M4	=	F.
	dx	+	ey	=	f

D, E en F become
D=L1^2/(2*EI) : E=-L1/EI : F=H7.

With subroutine TWOEQUATIONS of which the code is shown on the left below, follow R4 and M4 and then the reactions R3 and M3 can be calculated.

Fig.4a.
Σ mom.A =0
T*(L3+A1)-R4*L1+M4-M3=0 ⇒ M3=T*(L3+A1)-R4*L1+M4
Σ vert. =0
R3+R4-T=0 ⇒ R3=T-R4

Next these calculated values are added to the already determinated values.
R1=R1+R3 : R2=R2+R4 : M1=M1+M3 : M2=M2+M4
And then follows the next distributed load with

Next I and finally

End Sub

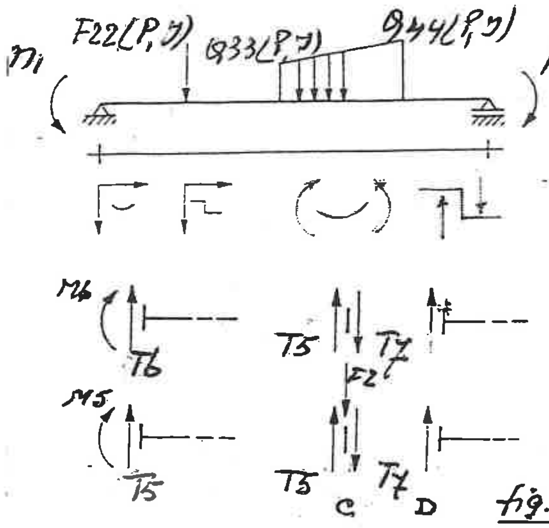


fig.1.

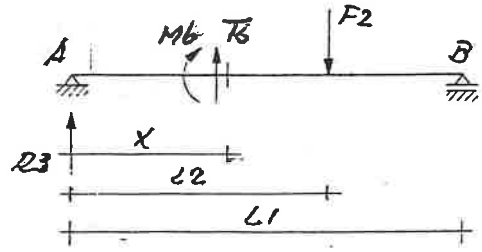


Fig.2a.

```
Private Sub T5M5XX()
'Calculation of transverse force T5
'and T7, and bending moment M5 at
'X meter from the 'left'
L1=L11(P)
T5=0 : T7=0 : M5=0

'The concentrated loads.
For I=1 TO NFB(P)
F2=F22(P,I) : L2=L22(P,I)
R3=F2*(L1-L2)/L1
If X<=L2 Then
T6=R3 : M6=R3*X
ElseIf X>L2 Then
T6=R3-F2 : M6=R3*X-F2*(X-L2)
End If
T5=T5+T6 : T7=T7+T6 : M5=M5+M6
If X=L2 Then
T7=T5-F2
End If
Next I
```

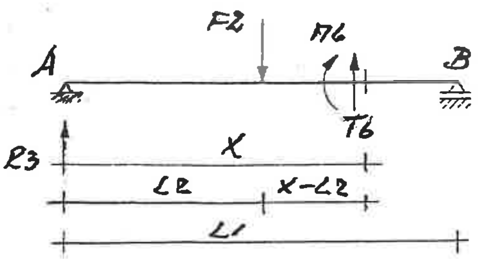


Fig.2b.

Private Sub T5M5XX()

Calculation of transverse/shear force and bending moment at X meter from the 'left'.
For a beam means 'left' the beam end where the beam axes system is placed.

Fig.1.
At X meter from the left member end transverse force T5 and bending momemnt M5 are calculated from 'left onto right'.
Then transverse force T5 is according to the shear sign directed upward, and bending moment M5 according to the bending sign to the right.
For each of the NFB(P) concentrated loads, and each of the NQB(P) distributed loads, and for the member end moments M1 and M2, trabsverse force T6 and momemt M5 are calculated which are added to the preceding values of T5 and M5.
Before the start values are T5=0 and M5=0.
Also transverse force T7 on the right of the section is calculated. The assumed direction of T7 from 'right onto left' is according to the shear sign directed downward. Before T7=0.
Beam length L1=L11(P).

'The concentrated loads.

Fig.2a.
For I=1 To NFB(P)
F2=F22(P,I) : L2=L22(P,I)

First reaction R3 is calculated.
Σ mom. B=0
R3*L1-F2*(L1-L2)=0 from which follows

R3=F2*(L1-L2)/L1.

Is X<L2 then T6=R3 and M6=R3*X.

Is X=L2 then F2 stands 'on the section'. Also then is T6=R3, this is the transverse force just on the left of the section. And the moment is, ofcourse, also now M6=R3*X.

Fig.2b.
Is X>L2 then is T6=R3-F2. Transverse force T is the resultant of R3 and F2.
The resulting moment is M6=R3*X-F2*(X-L2).
After that the calculated values are added to the preceding values with
T5=T5+T6 : T7=T7+T6 : M5=M5+M6.

Transverse force T5 and T7 are equal in magnitude and opposite directed, if 'between' the two there is no concentrated load F2.
Is X=L2 then F2 stand on the section and are T5 on the left, and T7 on the right, not equal in magnitude.

With Σ vert. =0 of the section, see fig.1, is T5-F2-T7=0 from which follows T7=T5-F2.
T7 upward acting on section D on the right of C is the resultant of T5 and F2. Also is T7=T7-F2.

Then the next concentrated load with
Next I.

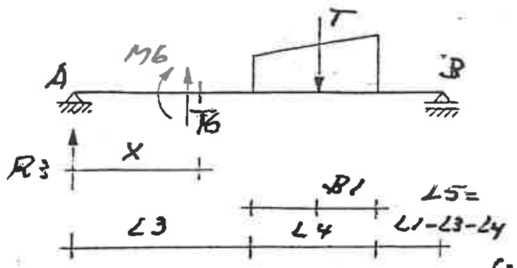
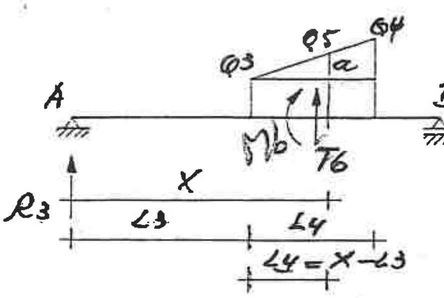


fig.3a



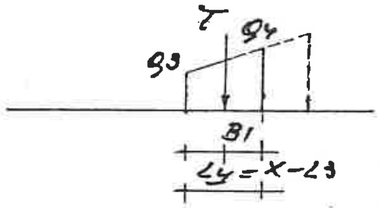


fig.3b.

```
'The distributed loads.
For I=1 To NQB(P)
Q3=Q33(P,I) : L3=L33(P,I)
Q4=Q44(P,I) : L4=L44(P,I)
QLOAD
R3=T*(B1+(L1-L3-L4))/L1
If X<=L3 Then
T6=R3 : M6=R3*X
Else If X>L3 And X<=L3+L4 Then
Q5=Q3+(Q4-Q3)*(X-L3)/L4
Q4=Q5 : L4=X-L3
QLOAD
T6=R3-T : M6=R3*X-T*B1
Else If X>L3+L4 Then
QLOAD
T6=R3-T : M6=R3*X-T*(X-L3-L4+B1)
End If
T5=T5+T6 : T7=T7+T6 : M5=M5+M6
Next I

'The member end moments M1 and M2.
R3=(M1-M2)/L1
T6=R3 : M6=R3*X-M1
T5=T5+T6 : T7=T7+T6 : M5=M5+M6

End Sub
```

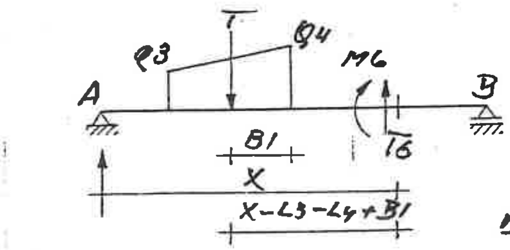


fig.3c.

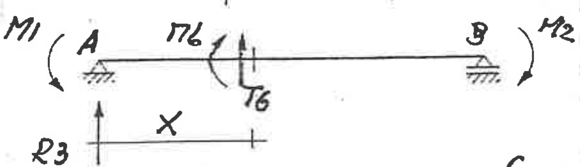


fig.4.

The distributed loads.

Fig.3a.
For I=1 To NQB(P)
Q3=Q33(P,I) : L3=L33(P,I)
Q4=Q44(P,I) : L4=L44(P,I)
With subroutine
QLOAD (page 3)
resultant T of the distributed load and distance B1 are calculated.
Now reaction R3 can be calculated.
worden onder andere resultante T van de verdeelde belasting, en afstand B1 berekend.
Σ mom. B =0
R3*L1-T*(B1+(L1-L3-L4) from which follows
R3=T*(B1+(L1-L3-L4))/L1.

Is X<=L3 then follows like with the concentrated loads
T6=R3 : M6=R3*X.

Fig.3b.
Is X>L3 (X=L3 has been already) and X<=L3+L4 then a part of the trapiziumform distributed load is needed. For that Q5 is calculated.
With similarity of triangles follows

a/(Q4-Q3)=(X-L3)/L4 from which
a=(Q4-Q3)*(X-L3)/L4 so that
Q5=Q3+(Q4-Q3)*(X-L3)/L4.

First for this trapeze are determinated new values of Q4 and L4,
Q4=Q5 : L4=X-L3.
Next once again with subroutine
QLOAD
resultant T and distance B1 can be calculated.
T6=R3-T is the resultant of R3 and T.
M6=R3*X-T*B1 is the resulting moment of the moments R3*X and T*B1.

The altered Q4 and L4 donot need to get back their original value because before the next distributed load first follows again
Q4=Q44(P,I) en L4=L44(P,I).

Fig.3c.
Finally, is X>L3+L4 then follows with subroutine
QLOAD
the calculation of T and B1. Then become
T6=R3-T and M6=R3*X-T*(X-L3-L4+B1). And after
End If
T5=T5+T6 : T7=T7+T6 : M5=M5+M6.
And then the next distributed load with
Next I.

The member end moments M1 and M2.

Fig.4.
With Σ mom. B=0 follows R3*L1+M2-M1=0 from which
R3=(M2+M1)/L1, so that

T6=R3 : M6=R3*X-M1 and next again
T5=T5+T6 : T7=T7+Y6 : M5=M5+M6.
And then the end of the subroutine with
End Sub.

Example.

Calculation of transverse forces with subroutine T5M5XX.

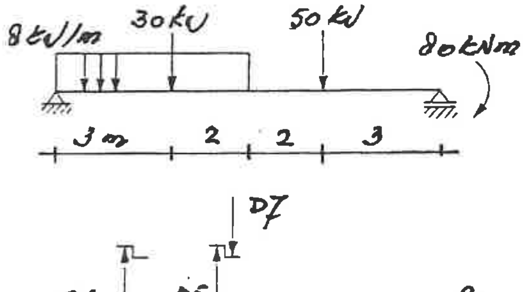


fig.1

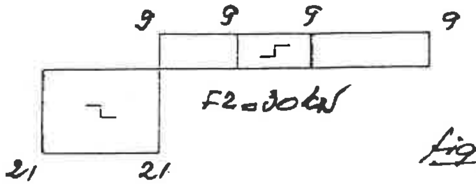


fig.2a

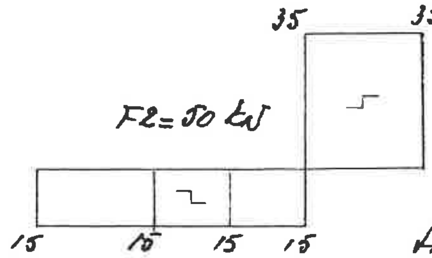


fig.2b

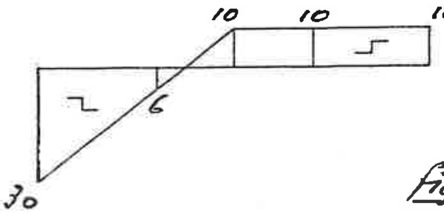


fig.2c

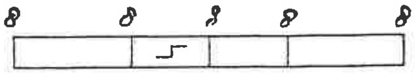


fig.2d

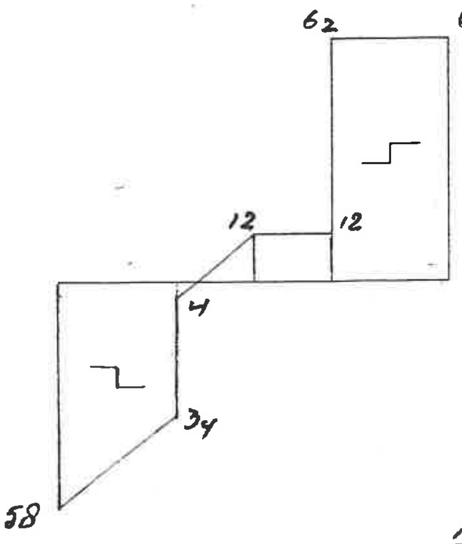


fig 2e

Fig.1.
For a given distance X from the left for each of the four load cases transverse force T6 is calculated, from left onto right as assumed directed upward.
After each calculation follows T5=T5+T6 and T7=T7+T6 and at the place of the concentrated load becomes T7=T7-F2.

Fig.2a, 2b, 2c en 2d.
The transverse force diagram for the concentrated loads of 30 and 50 kN, the uniformly distributed load of 8 kN/m and the member end moment of 80 kNm.

Fig. 2e.
The final transverse force diagram is the sum of fig.2a to 2d.
Here below is shown the order of calculation.

X= 0 m	T5= 0 kN	T7= 0 kN
T6= 21 kN	T5= 0+21= 21 kN	T7= 0+21= 21 kN
T6= 15	T5=21+15= 36	T7=21+15= 36
T6= 30	T5=36+30= 66	T7=36+30= 66
T6= -8	T5=66- 8= 58	T7=66- 8= 58

X= 3 m   T5= 0 kN   T7= 0 kN
Just left of the concentrated load of 30 kN is
T6= 21 kN   T5= 0+21= 21 kN   T7= 0+21= 21 kN

But X=L2 and F2=30 kN so that just right of the concentrated load T7=T5-F2=21-30= -9 kN
A negative answer, T7 from right onto left, is not directed downward but upward, thus another shear sign, above the zero line.

T6= 15	T5=21+15= 36	T7=-9+15= 6
T6= 6	T5=36+ 6= 42	T7= 6+ 6= 12
T6= -8	T5=42- 8= 34	T7=12- 8= 4

If the calculation gives a negative answer for T6, then T6 from left onto right is not directed upward as assumed, but downward, thus the opposite shear sign.

X= 5 m	T5= 0 kN	T7= 0 kN
T6= -9 kN	T5= 0- 9= -9 kN	T7= 0- 9= -9 kN
T6= 15	T5=-9+15= 6	T7=-9+15= 6
-10	T5= 6-10= -4	T7= 6-10= -4
T6= -8	T5=-4- 8=-12	T7=-4- 8=-12

X= 7 m	T5= 0 kN	T7= 0 kN
T6= -9 kN	T5= 0- 9= -9 kN	T7= 0- 9= -9 kN
T6= 15	T5=-9+15= 6	T7=-9+15= 6

X=L2 en F2=50 kN so that T7=T7-F2= 6-50=-44

T6=-10	T5= 6-10= -4	T7=-44-10=-54
T6= -8	T5=-4- 8=-12	T7=-54- 8=-62

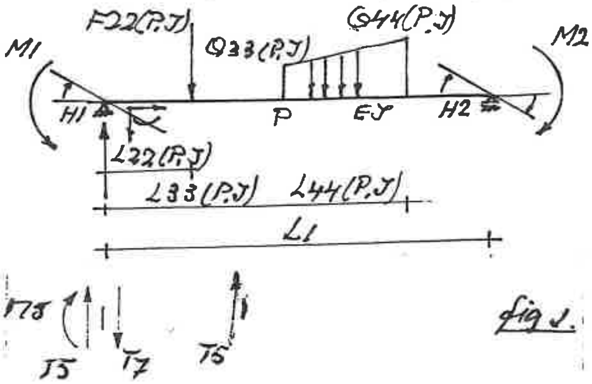


fig.1.

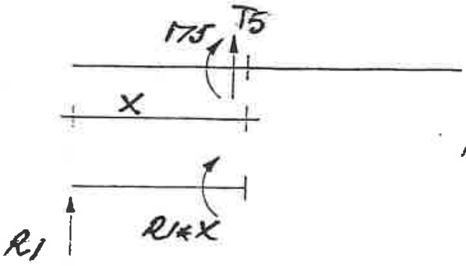


fig.2a.

fig.2b.

```
Private Sub T5M5X()
'Calculation of transverse force
'T5 and T7, and bending moment M5
'at X meter from the 'left'.
L1=L11(P)
T5=R1 : T7=R1 : M5=-M1
M5=M5+R1*X
'The concentrated loads.
For I=1 To NFB(P)
F2=F22(P,I) : L2=L22(P,I)
If X>L2 Then
T5=T5-F2 : T7=T7-F2
M5=M5-F2*(X-L2)
ElseIf X=L2 Then
T7=T7-F2
ElseIf X<L2 Then
Exit For
End If
Next I
```

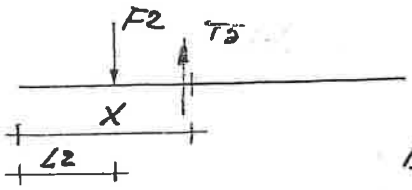


fig.3a.

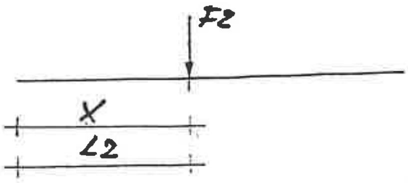


fig.3b.

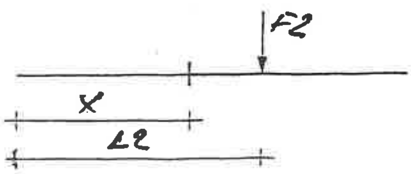


fig.3c

Private Sub T5M5X()

Calculation of transverse force and bending moment at X meter from the 'left', after using one of the subroutines BEAM1, BEAM2, or BEAM3.

Fig.1.
The calculated reactions R1 and R2,and eventually M1 and M2 when not being member end loads, arise due to all beam loads.
Directions of transverse forces and bending moments are like on page following from shear sign and bending sign belonging to the beam axis system.
Beam length is L1=L11(P).
At the beginning the transverse forces are
T5=R1 : T7=R1 for X=0,
and the bending moment, M5 is assumed to the right and M1 is assumed to the left, so M5=-M1.

Fig.2a.
At distance X start values T5, T7 are equal to the values in the beginning.

Fig.2b.
But reaction R1, due to all loads, gives a moment at X of R1*X to the right. So for that section at X the start value becomes
M5=M5+R1*X.
Shorter, T5=R1 : T7=R1 : M5=-M1+R1*X.

The concentrated loads.

```
For I= 1 To NFB(P)
F2=F22(P,I) : L2=L22(P,I)
```

Fig.3a.
If X>L2 Then
The T5 at distanc X is the resultant of the preceding T5 anf load force F2,
T5=T5-F2 : T7=T7-F2.
Moment M5 at X is the resultant of the preceding M5 and moment F2*(X-L2), so
M5=M5-F2*(X-L2).

Fig.3b.
ElseIf X=L2 Then
In this case T5 left of the section does not change, but T7 right of the section does.
T7 acting upward from left onto right on the section right of F2 is the resultant of the preceding T7 and F2, so
T7=T7-F2.
Moment M5 does not change, has the preceding value.

All load forces F2 with X<L2 do not contribute.
Therefore is written to leave the For-Next

```
ElseIf X<L2 Then
Exit For
End If
Next I
```

That's done 'save time' but with a few forces it is of no use.
By the way, this Exit For is only then correct when the load forces are numbered, put in, from left to right successively.

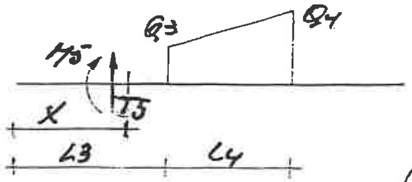


fig.4a.

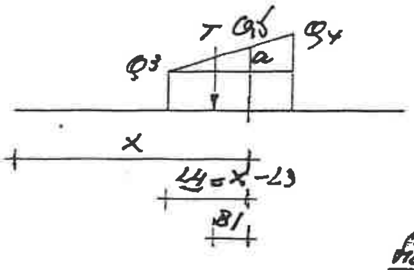


fig. 4b.

```
'The distributed loads.
For I=1 To NQB(P)
Q3=Q33(P,I) : L3=L33(P,I)
Q4=Q44(P,I) : L4=L44(P,I)
If X>L3 Then
If X>L3 And X<=L3+L4 Then
Q5=Q3+(Q4-Q3)*(X-L3)/L4
T=0.5*(Q3+Q5)*(X-L3)
B1=(2*Q3+Q5)*(X-L3)/(3*(Q3+Q5))
T5=T5-T : T7=T7-T
M5=M5-T*B1
ElseIf X>L3+L4 Then
T=0.5*(Q3+Q4)*L4
B1=(2*Q3+Q4)*L4/(3*(Q3+Q4))
T5=T5-T : T7=T7-T
M5=M5-T*(B1+(X-L3-L4))
End If
End If
Next I

End Sub
```

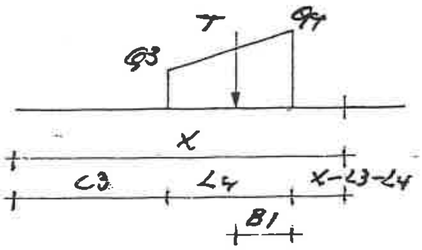


fig.4c.

The distributed loads.

```
For I=1 To NQB(P)
Q3=Q33(P,I) : L3-L33(P,I)
Q4=Q44(P,I) : L4=L44(P,I)
```

Fig.4a.
Is X<=L3 then the calculated T5, T7 and M5 for X from the left do not change.
Fig.4b and 4c.
When X is larger than X3, then T5, T7 and M5 change and one of the two possible calculations is carried out. Therefore the first If-End with If X>L3 then.

The first possibility.

Fig.4b.
If X>L3 And X<=L3+L4 Then
The influence of the part of the distributed load left of the section is calculated. For that Q5 is calculated as follows.

a/(Q4-Q3)=(X-L3)/L4 or a=(Q4-Q3)*(X-L3)/L4

so that

Q5=Q3+(Q4-Q3)*(X-L3)/L4.

The resultant T of that part of the distributed load is
T=0.5*(Q3+Q5)*(X-L3)

and distance B1 becomes, see page
B1=(2*Q3+Q5)*(X-L3)/(3*(Q3+Q5)), and then follow

T5=T5-T : T7=T7-T and

M5=M5-T*B1.

The second possibility.

Fig.4c.
ElseIf X>L3+L4 Then
Now the total distributed load is on the left of the section. Then follow as before

T=0.5*(Q3+Q4)*L4 and

B1=(2*Q3+Q4)*L4/(3*(Q3+Q4)) and then become

T5=T5-T : T7=T7-T and the bending moment

M5=M5-T*(B1+(X-L3-L4)).

Then two times End If and then the next distributed load with
Next I and finally

End Sub

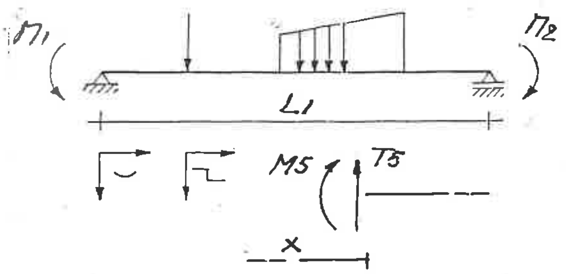


Fig.2.

```
Private Sub MMAXM5()
'Calculation of the largest ben-
'ding moment and the moment zero
'points.
NM=0 : L1=L11(P)
For X=0 To L1+0.01 Step 0.01
T5M5XX

If X=0 Then
M7=M5 : T3=T5
NM=NM+1
MMAXX(P,NM)=M5 : LM(P,NM)=X

ElseIf X>0 And X<L1 Then

If M5>=0 And M7<0 Or _
            M5<=0 And M7>0 Then
NM=NM+1
MMAXX(P,NM)=M5 : LM(P,NM)=X
End If
M7=M5

If T5<=0 And T3>0 Or _
           T5>=0 And T3<0 Then
NM=NM+1
MMAXX(P,NM)=M5 : LM(P,NM)=X
End If
T3=T5

ElseIf X>=L1 Then
X=L1 : T5M5XX
NM=NM+1
MMAXX(P,NM)=M5 : LM(P,NM)=X
End If

Next X

End Sub
```

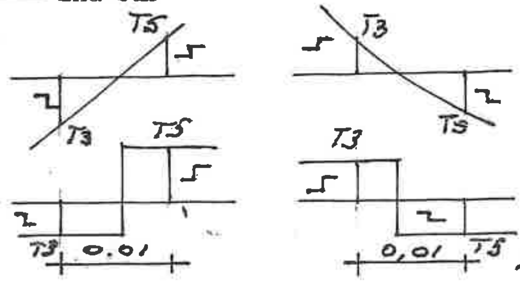


Fig.3.

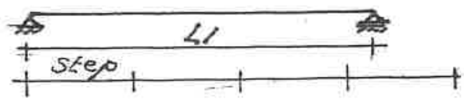


Fig.4.

Private Sub MMAXM5()

Calculation of mamimum moments and moment zero points which are stored in MMAXX(P,NM) and their distances X from the 'left' in LM(P,NM). Start value of counter NM=0.

Fig.1
For X=0 To L1+0.01 Step 0.01
T5M5XX (page 9)
At each centimeter transverse force T5 and bending moment M5 are calculated.

If X=0 Then

The first values to compare with become
M7=M5 : T3=T5.
The moment is stored, it might be the largest noment in case of a clamp.
(Or M7=-M1 and T5=R1, the values found with BEAM1, BEAM2 or BEAM3.)

ElseIf X>0 and X<L1 Then
The new values T5 and M5 have been calculated with T5M5XX and are compared with the preceding values.

The moment zero points.
Fig.2.
There are two possible ways how the bending moment line can pass the zero line, a curve or straigth line. If one of the conditions is satisfied then moment and distance are stored. After If-End If the new value to compare with becomes M7=M5.

The maximum moments.
Fig.3.
A maximum moment occurs when the tranverse force line passes the zero line.
Also in this case two possibilities.
After If-End If the new value to compare with becomes T3=T5.

ElseIf X>=L1+0.01 Then
Fig.4.
Depending on length L1 and step size, X can be equal or larger than L1. If X is larger than L1 then X becomes X=L1 and M5 is calculated with T5M5XX, and stored.
(Or M5=-M2.)

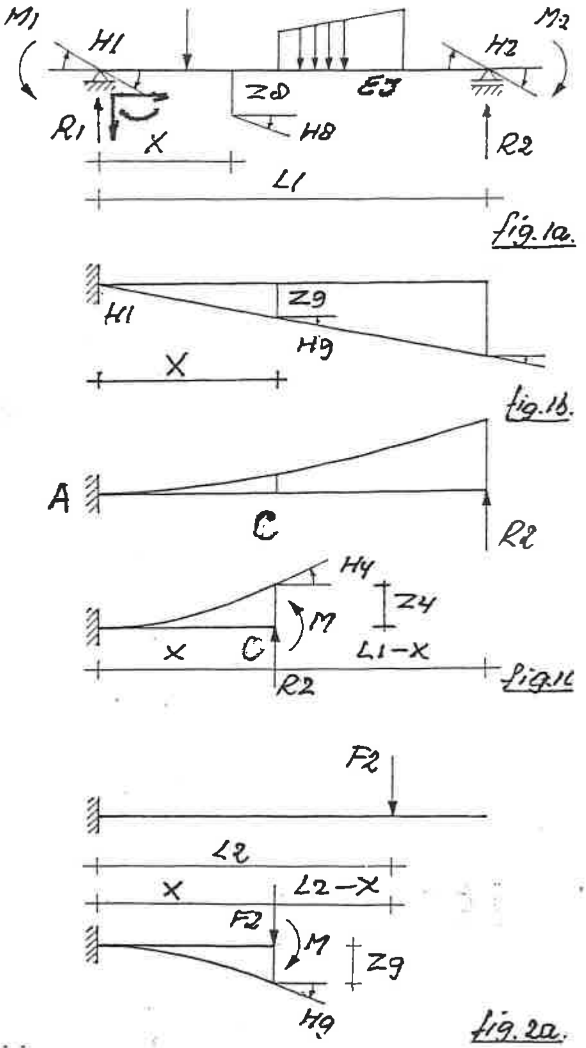
Next X

End Sub

Later the largest absolute value of all found values will be determined. (page)

Remark. As step size is taken 1 cm, accurate enough. With 0.001 meter, an error occurs, after ElseIf X>=L1. Subscript out of range, NM not large enough of MMAX(P,NM) no matter how large NM is in the declaration. For X=L1 the calculation is carried out again and again, but why......? To avoid this one can write just before End If, Exit For. In that case the calculation for X=L1 will be carried out just one time.

Private Sub H8Z8XX()



Calculation of slope deflection H8 and displacement Z8 at X meter from the 'left', the member end where the member axes system is placed. H8 assumed to the right, Z8 assumed downward.

First start values H8=0 and Z8=0

Fig.1a.
Due to all loads together,
NFB(P) concentrated load forces,
NQB(P) distributed loads, and
the moments M1 and M2, arise
the reactions R1 and R2, and
the slope deflections H1 and H2.

<u>Slope deflection H9 and displacement Z9 due to angle H1.</u>
Fig.1b.
If the unloaded beam is thought to clamped under angle H1, assumed to the right, then become

H9=H1 to the right and

Z9=H1*X downward.

<u>H9 and Z9 due to reaction R2.</u>
Fig.1c.
The beam now is clamped horizontally on the left at A. When loaded with R2 then on the section at C arise, from right on to left, a force R2 upward and a moment M=R2*(L1-X) to the left.
(Force R2 is decomposed into a force R2 at C and a couple with moment R28(L1-X).)
R2 is assumed upward then the beam bends as drawn in the figure.
Then follow

H4=R2*X^2/(2*EI)+M*X/EI to the left and

Z4=R2*X^3/(3*EI)+M*X^2/(2*EI) upward.

The results of fig.1b and 1c are added to get H8 and Z8 found until now.

H8=H8+H9-H4 : Z8=Z8+Z9-Z4.

<u>H9 and Z9 due to the concentrated loads.</u>
Fig.2a.

For I=1 To NFB(P)
F2=F22(P,I) : L2=L22(P,I)

The beam is clamped horizontally at A and loaded with force F2.

If X<=L2 Then
Due to this force arise from right onto left on the section a force F2 downward and a moment M=F2*(L2-X) to the right.
The beam bends by F2 is drawn and gives the H9 and Z9 as the figure shows. Then follow applying the formulas like used for Fig 1c

H9=F2*X^2/(2*EI)+M*X^2/EI to the right and

Z9=F2*X^3/(3*EI)+M*X^2/(2*EI).

```
Private Sub H8Z8XX()
'Calculation of slope deflection H8
'and displacement Z8 at X meter
'from the left.

L1=L11(P)
H8=0 : Z8=0

'Due to angle H1.
H9=H1 : Z9=H1*X

'Due to the reaction R2.
M=R2*(L1-X)
H4=R2*X^2/(2*EI)+M*X/EI
Z4=R2*X^3/(3*EI)+M*X^2/(2*EI)
H8=H8+H9-H4 : Z8=Z8+Z9-Z4

'The concentrated loads..
For I=1 To NFB(P)
F2=F22(P,I) : L2=L22(P,I)
If X<=L2 Then
M=F2*(L2-X)
H9=F2*X^2/(2*EI)+M*X/EI
Z9=F2*X^3/(3*EI)+M*X^2/(2*EI)
```

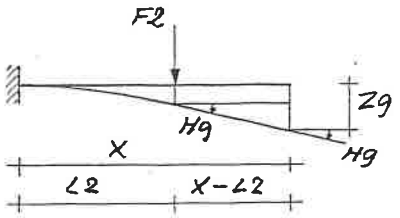


fig.2a

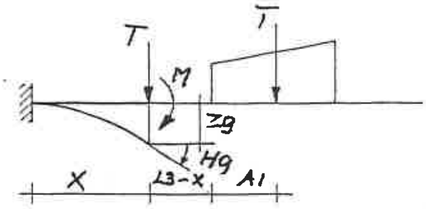


fig.3a

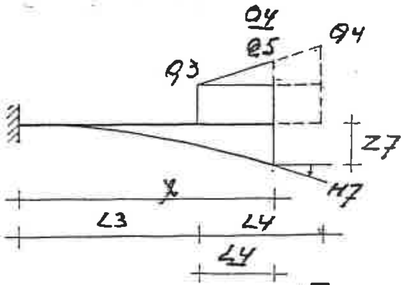


fig.3b

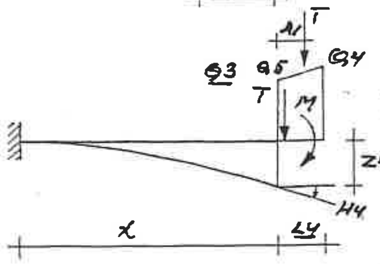


fig.3c

```
ElseIf X>L2 Then
H9=F2*L2^2/(2*EI)
Z9=F2*L2^3/(3*EI)+H9*(X-L2)
End If
H8=H8+H9 : Z8=Z8+Z9
Next I

'The distributed loads.
For I=1 To NQB(P)
Q3=Q33(P,I) : L3=L33(P,I)
Q4=Q44(P,I) : L4=L44(P,I)
If X<=L3 Then
QLOAD          page
M=T*(L3-X+A1)
H9=T*X^2/(2*EI)+M*X/EI
Z9=T*X^3/(3*EI)+M*X^2/(2*EI)
ElseIf X>L3 And X<L3+L4 Then
Q5=Q3+(Q4-Q3)*(X-L3)/L4
Q4=Q5 : L4=X-L3
QLOAD
H9=H7 : Z9=Z7
Q4=Q44(P,I) : L4=L44(P,I)
Q3=Q5 : L4=L3+L4-X
QLOAD
M=T*A1
H4=T*X^2/(2*EI)+M*X/EI
Z4=T*X^3/(3*EI)+M*X^2/(2*EI)
H9=H9+H4 : Z9=Z9+Z4
```

Fig.2b.
ElseIf X>L2 Then

On the left of load force F2 the beam is bent and on the right of F2 the beam is straight. Then at the section at X arise

H9=F2*L2^2/(2*EI)   and
Z9=F2*L2^3/(3*EI)+H9*(X-L2).

End If and then before Next I
H8=H8+H9 : Z8=Z8+Z9 and then
Next I for the next F2=F22(P,I).

<u>H9 and Z9 due to the distributed loads.</u>
Fig.3a.

For I=1 To NQB(P)
Q3=Q33(P,I) : L3=L33(P,I)
Q4=Q44(P,I) : L4=L44(P,I) and then first

If X<=L3 Then
Then follows subroutine QLOAD (page 3) to calculate force T and distance A1.
At section C arise from right onto left force T downward and moment M=T*(L3-X+A1) to the right, then H9 and Z9 become

H9=T*X^2/(2*EI)+M*X/EI   and
Z9=T*X^3/(3*EI)+M*X^2/(2*EI).

Then after End If these values are added to the preceding values of H8 and H9,
H8=H8+H9 : Z8=Z8+Z9 and then Next I, see next page.

Fig.3b.
ElseIf X>L3 And X<L3+L4 Then
(see remark next page)

First the effect of the left part of the trapeze is considered. Again subroutine QLOAD is used but first Q5 is needed like on page 10 .
Q5=Q3+(Q4-Q3)*(X-L3)/L4.

For the left part, a trapeze, become first
Q4=Q5 : L4=X-L3 and then follows

QLOAD which gives H7 and Z7 and then become
H9=H7 : Z9=Z7.

Fig.3c.
Before calculating the effect of the right part of the trapeze some values are re-established,
Q4=Q44(P,I) : L4=L44(P,I) and after that for the 'new' trapeze become
Q3=Q5 : L4=L3+L4-X and then again
QLOAD which gives T and A1. Thus a force T and a moment M=T*A1 which cause H4 And Z4,

H4=T*X^2/(2*EI)+M*X/EI   and
Z4=T*X^3/(3*EI)+M*X^2/(2*EI)   which are added

to the preceding values of H9 and Z9, sum of fig.3b and 3c, H9=H9+H4 : Z9=Z9+Z4 and then after End If

H8=H8+H9 : Z8=Z8+Z9 and next distributed load with Next I.

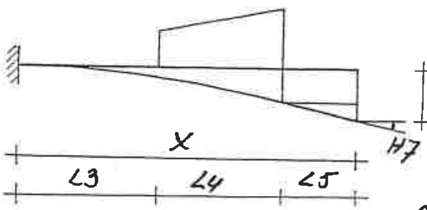


Fig.3d.

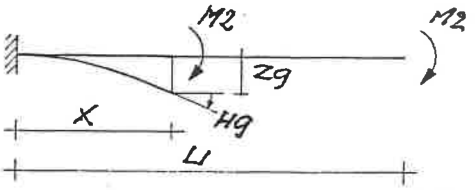


Fig.4.

```
ElseIf X>=L3+L4 Then
L5=X-L3-L4
QLOAD
H9=H7 : Z9=Z1
End If
H8=H8+H9 : Z8=Z8+Z9
Next I

'The member end moment M2.
H9=M2*X/EI : Z9=M2*X^2/(2*EI)
H8=H8+H9 : Z8=Z8+Z9

'Member end displacements.
H9=(REZ-LEZ)/L1
Z9=LEZ+(REZ-LEZ)*X/L1
H8=H8+H9 : Z8=Z8+Z9

End Sub
```

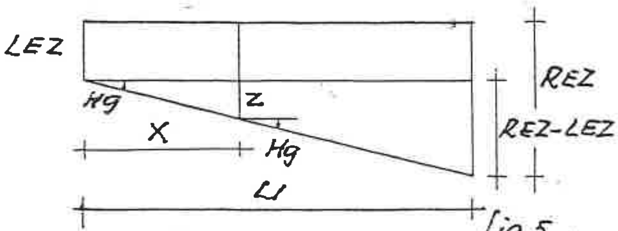


Fig.5.

Suppose X=L1=6.

Before the first QLOAD is
Q3=7
Q5=Q3+(Q4-Q3)*(X-L3)/L4 or
Q5= 7+ (0-7) (4)/4= 7-7*(1)=0
And with Q4=Q5 is Q4=0 and L4=X-L3=4.
So Q3=7, Q4=0 and L4=4 which gives no problem. See B1 below.

Then the second time before QLOAD.
Q4=Q44(P,I)=0 and L4=L44(P,I)=4.
Q3=Q5 is Q3=0.
L4=L3+L4-X=2+4-6=0.
So Q3=0, Q4=0 and L4=0.
With subroutine QLOAD, page , A1 is calculated, but first B1,

B1=(2*Q3+Q4)*L4/(3*(Q3+Q4)) and division by zero is not possible.

Fig.3d.
ElseIf X>=L3+L4 Then

Again subroutine QLOAD is used but before distance L5 must be determined,
L5=X-L3-L4.
Subroutine QLOAD gives slope deflection H7 and displacement Z1, after that become
H9=H7 : Z9=Z1 and after End If again

H8=H8+H9 : Z8=Z8+Z9 and then
Next I.

H9 and Z9 due to member end moment M2.
Fig.4.
From the right end to the section at X meter from the left the bending moment is constant, so the moment is M2 to the right which bends the beam downward. Then become

H9=M*X/EI : Z9=M*X^2/(2*EI) and added with

H8=H8+H9 : Z8=Z8+Z9.

Slope deflection H9 and displacement Z9 due to member end (support) displacements.
Fig.5.
LEZ is the displacement at the left member end, where the member axes system is placed, and REZ is the displacement at the right member end. Like Z8 the are assumed downward, and REZ>LEZ. (Or REZ<LEZ but then the figure is else and H9 is then to the left instead of to the right, so the equation for Z9 will look different.)
Wit similarity of triangles follows
Z/(REZ-LEZ)=X/L1 or Z=(REZ-LEZ)*X/L1 so that

Z9=LEZ+(REZ-LEZ)*X/L1.

The tangent of H9≈H9 because the displacements are very small comparing with the length of the beam, so
H9=(REZ-LEZ)/L1 and finally again
H8=H8+H9 : Z8=Z8+Z9

End Sub

Remark.

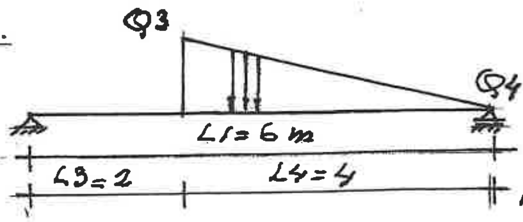


Fig.6.

Fig.6. See the comment on the left

Instead of writing
If X>L3 And X<=L3+L4 is written

If X>L3 And X<L3+L4 (= sign is omitted).

And therefore not
X>L3+L4 but X>=L3+L4 (= sign is added)

If is written If X>L3 And X<=L3+L4 Then the calculation leads to division by zero in cases like such as the figure shows where L3+L4 is equal to beam length L1.

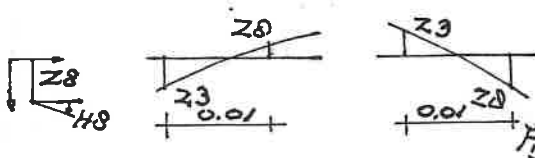


Fig.1.

```
Private Sub ZMAXZ8()
'Calculation of the largest dis-
'placement/bending and the ben-
'ding zero points.
NZ=0 : L1=L11(P) : EI=EII(P)
For X=0 To L1+0.01 Step 0.01
H8Z8XX        page 15

If X=0 Then
Z3=Z8 : H3=H8 : NZ=NZ+1
ZMAXX(P,NZ)=Z8 : LZ(P,NZ)=X

ElseIf X>0 And X<L1 Then

If Z8<=0 And Z3>0 Or _
   Z8>=0 And Z3<0 Then
NZ=NZ+1
ZMAXX(P,NZ)=Z8 : LZ(P,NZ)=X
End If
Z3=Z8

If H8<=0 And H3>0 Or _
   H8>=0 And H3<0 Then
NZ=NZ+1
ZMAXX(P,NZ)=Z8 : LZ(P,NZ)=X
End If
H3=H8

ElseIf X>=L1 Then
X=L1 : H8Z8XX
NZ=NZ+1
ZMAXX(P,NZ)=Z8 : LZ(P,NZ)=X
Exit For
End If

Next X

ZMAX=0
For I=1 To NZ
If Abs(ZMAXX(P,I))>Abs(ZMAX) Then
ZMAX=ZMAXX(P,NZ) : X=LZ(P,I)
End If
Next I
NZ=NZ+1
ZMAXX(P,NZ)=ZMAX : LZ(P,NZ)=X
NZZ(P)=NZ

End Sub
```

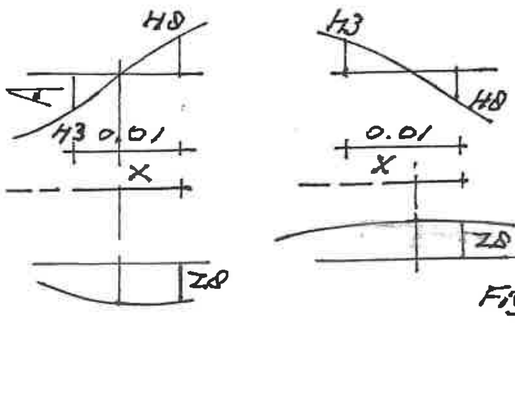


Fig.2

Private Sub ZMAXZ8()

Calculation of the largest displacement Z8 and the displacement zero points which are stored in ZMAXX(P,NZ) and their distances X from the 'left' in LZ(P,NZ). Start value counter NZ=0. See page 14 with subroutine MMAXM5.

For X=0 To L1+0.01 Step 0.01
H8Z8XX

At each centimeter slope deflection H8 and displacement Z8 are calculated with subroutine H8Z8XX.
If X=0 Then
The first values to compare with become slope deflection H3=H8 and displacement Z3=Z8.
This first displacement and distance X is stored with
NZ=NZ+1
ZMAXX(P,NZ)=Z8 : LZ(P,NZ)=X.

ElseIf X>0 And X<L1 Then

The displacement zero points.
Fig.1.
There are two possibilities of the way the bending line passes the zero line,
If Z8>=0 And Z3<0 Or Z8<=0 And Z3>0.
If one of these wo cases apply then storing,
NZ=NZ+1
ZMAXX(P,NZ)=Z8 : LZ(P,NZ)=X.
This Z8 is zero, written is Z8 to see in the examples how close to zero the calculated value is.
After End If becomes Z3=Z8 for the comparison of the next calculated Z8 with Z3.

The maximum displacements.
Fig.2.
A maximum displacement occurs when the slope deflection line (elastic curve) passes the zero line. Also here two cases to check.
If H8>=0 And H3<0 Or H8<=0 And H3>0.
If a case applies displacement Z8 and distance X are stored like above.
After End If becomes H3=H8 for the comparison of the next H8 with H3.

ElseIf X>=L1 Then

X may be exactly L1, or larger, taken care of with L1+0.01. For X=L1 follows calculation with H8Z8XX and values are stored. Next Exit For because calculations may not stop...
After Next I the largest displacement is determined and added to the list of the already NZ values found.
ZMAX is the value to compare with, start maximum value is ZMAX=0.
For I=1 To NZ
If Abs(ZMAXX(P,I))>Abs(ZMAX) Then, if so the the largest is kept with ZMAX=ZMAXX(P,I) and the concerning distance with X=LZ(P,I).
After Next I the number of the largest found value is NZ=NZ+1, then
ZMAXX(P,NZ)=ZMAX : LZ(P,NZ)=X
and the number of stored values is NZZ(P)=NZ.

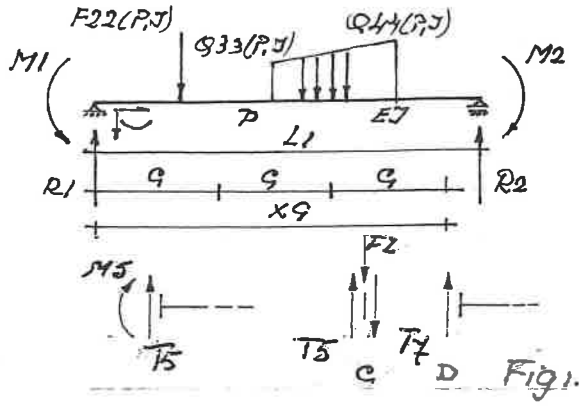


Fig.1.

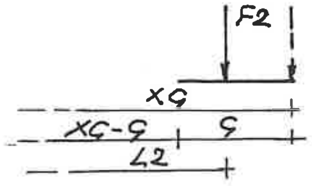


Fig.2.

```
Private Sub T5M5G()

NB=0 : L1=L11(P)
For XG=0 To L1+G Step G
If XG=0 Then
X=XG : T5M5XX           page 9
T5M5

ElseIf XG>0 And XG<L1 Then
For I1=1 To NFB(P): L2=L22(P,I1)
If L2>XG-G And L2<XG Then
X=L2 : T5M5XX
T5M5
End If
Next I1
X=XG : T5M5XX
T5M5

ElseIf XG>=L1 And XG<L1+G Then
For I1=1 To NFB(P): L2=L22(P,I1)
If L2>XG-G Then
X=L2 : T5M5XX
T5M5
End If
Next I1
X=L1 : T5M5XX
T5M5

End If
Next XG : NBC(P)=NB
End Sub
```

```
Private Sub T5M5()
NB=NB+1 : LB(P,NB)=X
NBL(P,NB)=T5 : NBR(P,NB)=T7
NBM(P,NB)=M5
End Sub
```

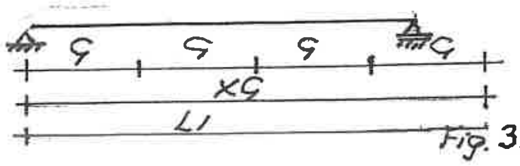


Fig. 3.

Private Sub T5M5G()

Calculation of transverse forces T5 and T7 and bending moment M5 at each G meter and at the places of the concentrated loads. (See subroutine N5G for normal forces, page 4-19) Fig.1.
The number of sections is counted with NB, start value NB=0, which will be stored with NBC(P)=NB after Next XG. (Or in subroutine T5M5 before End Sub.)

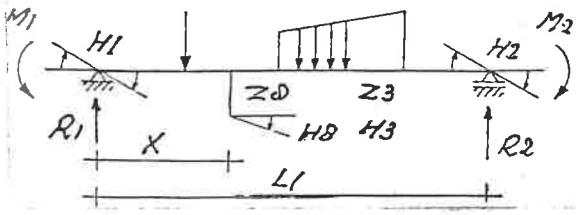
For XG=0 To L1+G Step G

If XG=0 Then
X=XG : T5M5XX and T5M5.
First becomes X=XG and then follows subroutine T5M5XX (page 9) to calculate T5, T7 and M5. After that with subroutine T5M5 the calculated values and the belonging distance are stored, first NB=NB+1 and then
LB(P,NB)=X
NBL(P,NB)=T5 on the left of the section, and
NBR(P,NB)=T7 on the right of the section,
NBM(P,NB)=M5 the bending moment at distance X from the 'left'.
(Or first X=0 : T5=R1 : T7=R1 : M5=-M1 : T5M5 instead of X=XG : T5M5XX.)
Fig.2 and 1.
ElseIf XG>0 And XG<L1 Then
Suppose there are load forces then next code is carried out.
For I1=1 To NFB(P)
L2=L22(P,I1)
The condition right of section C and up to section D is given with
If L2>XG-G And L2<XG Then,
for each I1 this condition is checked. If satisfied then follows for the force right of C and left of D
X=L2 : T5M5XX and T5M5.
End If
Next I1
For each step G given with XG the calculation will be carried out, if there is a load force on that section or not, so after Next I1
X=XG : T5M5XX and T5M5.
Fig.3.
ElseIf XG>=L1 And XG<L1+G Then
There is written XG<L1+G, and not X5<=L1+G with = sign. If XG=L1 then a calculation is carried out. With the next step is XG=L1+G and then after Next I1 one more time for distance X=L1 tranverse forces T5 and T7, and bending moment M5 would be calculated. So no = sign.
This is the last condition to be checked. If XG>=L1 then there might be a part of a step G with load forces. So for
I1=1 To NFB(P) is L2=L22(P,I1) and follows
L2=L22(P,I1) and follows
If L2>XG-G Then, and if so T5,T7 and M5 are calculated. And then finally after Next I1

X=L1 : T5M5XX and T5M5.
(Or instead, T5=-R2 : T7=-R2 : M5=-M2 : T5M5.)
After the last step after Next G becomes the number of sections NBC(P)=NB.

End Sub

Private Sub H8Z8G()




```
Private Sub H8Z8G()
NC=0 : L1=L11(P)
For XG=0 To L1+G Step G
If XG=0 Then
X=XG : H8Z8XX
H8Z8

ElseIf XG>0 And XG<L1 Then
For I1=1 To NFB(P): L2=L22(P,I1)
If L2>XG-G And L2<XG Then
X=L2 : H8Z8XX
H8Z8
End If
Next I1 : X=XG : H8Z8XX
H8Z8

ElseIf XG>=L1 And XG<L1+G Then
For I1=1 To NFB(P): L2=L22(P,I1)
If L2>XG-G Then
X=L2 : H8Z8XX
H8Z8
End If
Next I1 : X=L1 : H8Z8XX
H8Z8
End If
Next XG : NCC(P)=NC
End Sub
```

```
Private Sub H8Z8()
NC=NC+1 : LC(P,NC)=X
NH8(P,NC)=H8 : NZ8(P,NC)=Z8
End Sub
```

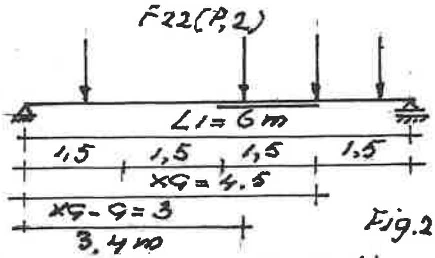


Fig.2.

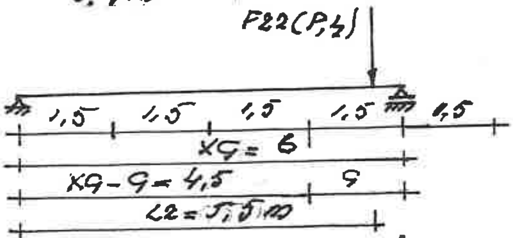


Fig.3.

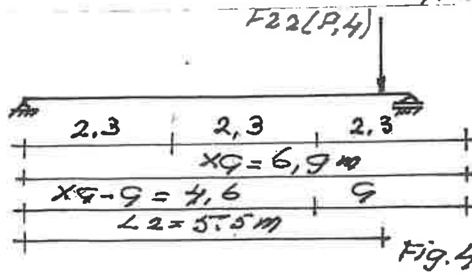


Fig.4.

Fig.1.
Calculation of slope deflection H8 and displacement Z8 each G meter from the 'left' and at places of the concentrated load forces.

This subroutine is similar to subroutine T5M5G of the preceding page.
The sections are counted with NC.
H8 and Z8 at distance X from the 'left' are calculated with subroutine H8Z8XX (page 15) and the results stored with subroutine H8Z8.

First NC=NC+1 and then the length X with LC(P,NC)=X, then slope deflection H8 with NH8(P,NC)=H8 and displacement Z8 with NZ8(P,NC)=Z8.

By the way, one cannot write code like X=L2 : H8Z8XX : H8Z8 because one subroutine must not follow another with : on the same line.

Considerations of step G, of importance for the transverse forces to be calculated on the preceding page.
Fig.2.
Here is 4 times step G=1,5m equal to L1=6 m.
ElseIf XG>0 And XG<L1 Then
In this case step 4 is excluded. Suppose step 3 with two forces F22(P,I1).

I1=1 L2=L22(P,1)=2,6 m
L2=2,6>XG-G=4,5-1,5=3 And L2=2,6<XG=4,5 ?
2,6>3 And 2,6<4,5 ? no, next force.

I1=2 L2=L22(P,2)=3,4 m
L2=3,4>3 And L2=3,4<4,5 ? yes then X=L2=3,4 and H8 and Z8 are calculated.

I1=3 L2=L22(P,3)=4,5 m
L2=4,5>3 And L2=4,5<4,5 ? no, next force.

But at this place with F2 the calculation will be carried out after the last force is checked, so after Next I1. If there is not a force at this place the calculation will be carried out as well.

Fig.3.
For the step from 4,5 to 6 meter follows
ElseIf XG>=L1 And XG<L1+G Then
XG=6>=L1=6 And XG=6<6+1,5=7,5 ?
6>=6 And 6<7,5? yes

I1=4 L2=L22(P,4)=5,5 m
L2=5,5>XG-G=6-1,5=4,5 ? 5,5>4,5 ? yes, then X=L2 : H8Z8XX and H8Z8, and after Next I1 follows the calculation for X=L1.

Fig.4.
Now with step G=2.3 m. The third step.
ElseIf XG>=L1 And XG<L1+G Then
XG=6,9>=6 And XG=6,9<6+2,3=8,3 ? yes,
I1=4 L2=L22(P,4)=5,5 m
L2=5,5>XG-G=6,9-2,3=4,6 ? 5,5>4,6 ? yes, then X=L2 : H8Z8XX and H8Z8, and after Next I1 follows the calculation for X=L1.

```
Private Sub CONSTRMATCCCBEAM
N=2*N9
For I=1 To N : For J=1 To N
CC(I,J)=0 : Next J : Next I
```

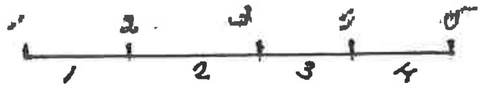
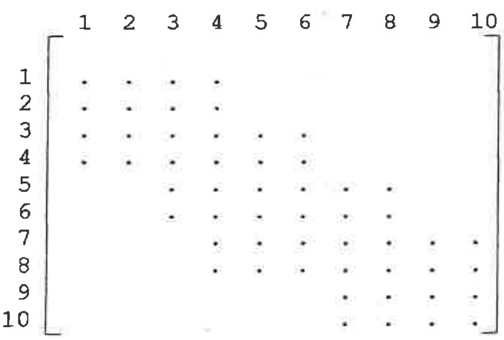


Fig.1.

A	B	-A	B		1,1	1,2	1,3	1,4
B	D	-B	E		2,1	2,2	2,3	2,4
-A	-B	A	-B		3,1	3,2	3,3	3,4
B	E	-B	D		4,1	4,2	4,3	4,4

S5

```
For P=1 To P9 : L=LL(P) : H=HH(P)
EI=EII(P)
MEMBERMATS5CBEAM
TT(1)=2*L-1 : TT(2)=2*L
TT(3)=2*H-1 : TT(4)=2*H
For I=1 To 4 : I1=TT(I)
For J=1 To 4 : J1=TT(J)
CC(I1,J1)=CC(I1,J1)+S5(I,J)
Next J
Next I
Next P
End Sub
```



CC

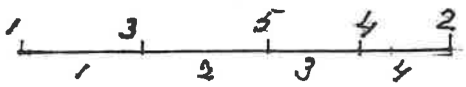
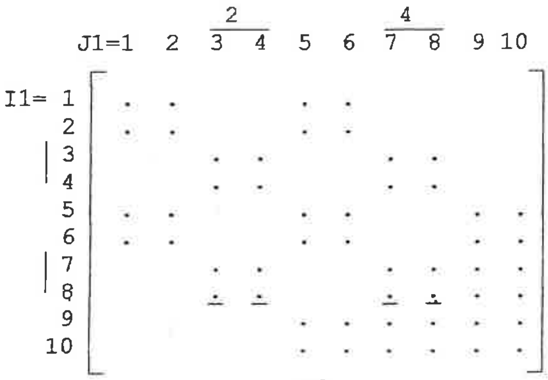


Fig.4.



CC

<u>Private Sub CONSTRMATCCCBEAM()</u>

Forming construction stiffness matrix CC of continuous beams.

Fig.1.
This continuous beam is divided into P9=4 four members and N9=5 five joints which are regularly numbered.
For each joint I there is
a vertical displacement UV(I), and
a joint rotation UR(I).
The number of equations then is N=2*N9=2*5=10
First all elements of construction matrix CC are set zero.
For I=1 To N : For J=1 To N
CC(I,J)=0 : Next J : Next I
For each member P with
lowest meber end number L=LL(P) and
highest member end number H=HH(P)
is the bending stiffness EI=EII(P).
With subroutine
<u>MEMBERMATS5CBEAM</u> (next page)
for each member the elements of member matrix S5 are calculated and after that placed in matrix CC.
Fig.2.
There are no hingy member ends, then the S5's look like as shown on the left.
and there are no elements equal to zero. On the main diagonal of CC all elements have a value uneqaul to zero.
Each of the four rows I=1 To 4 of S5 are put into CC for J=1 To 4 with
CC(I1,J1)=CC(I1,J1)+S5(I,J).
Fig.3.
Because of the regular joint numbering arises in construction matrix CC a 'band' of elements around the main diagonal.

Fig.4.
With an unregular joint numbering the band disappears, matrix CC will look quite differently.

Take for example matrix S5 of member 4 with
L=2 and H=4, then become
TT(1)=2*L-1=2*2-1=3 and TT(2)=2*L=2*2=4,
TT(3)=2*H-1=2*4-1=7 and TT(4)=2*H=2*4=8.

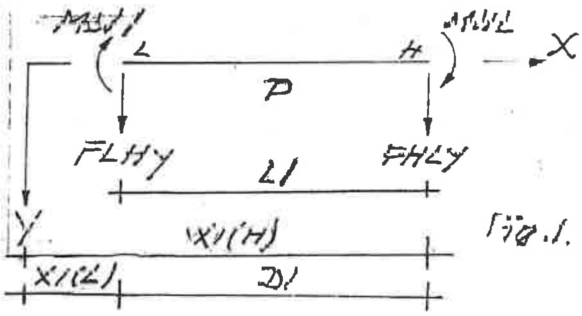
Row I=1 with I1=TT(1)=3 and J1=TT(J)=3,4,7,8,
row I=2 with I1=TT(2)=4 and J1=TT(J)=3,4,7,8,
row I=3 with I1=TT(3)=7 and J1=TT(J)=3,4,7,8.

Row I=4 met I1=TT(I)=TT(4)=8

```
J=1  J1=TT(J)=TT(1)=3  CC(8,3)=   0    +S5(4,1)
J=2  J1=TT(J)=TT(2)=4  CC(8,4)=   0    +S5(4,2)
J=3  J1=TT(J)=TT(3)=7  CC(8,7)=CC(8,7)+S5(4,3)
J=4  J1=TT(J)=TT(4)=8  CC(8,8)=CC(8,8)+S5(4,4)
```

CC(8,3) and CC(8,4) did not yet have a value, so still zero.
CC(8,7) had already the value S5(2,1), and
CC(8,8) had already the value S5(2,2) of member 3.

It is the joint numbering which determines how matrix CC will look like, and not the member numbering.




```
Private Sub MEMBERMATS5CBEAM()

D1=X1(H)-X1(L)
L1=Sqr(D1^2).
If NL(P)=0 And NH(P)=0 Then
A=12*EI/L1^3 : B=6*EI/L1^2
D=4*EI/L1 : E=2*EI/L1
If D1<0 Then B=-B
FILLINGS5CBEAM

ElseIf NL(P)=1 And NH(P)=1 Then
A=0 : B=0 : D=0 : E=0
FILLINGS5CBEAM

Else If NL(P)=1 Or NH(P)=1 Then
A=3*EI/L1^3 : B=3*EI/L1^2
D=3*EI/L1

If NL(P)=1 Then
If D1<0 Then B=-B
FILLINGS5CBEAM
For I=1 To 4
S5(2,I)=0 : S5(I,2)=0
Next I

ElseIf NH(P)=1 Then
If D1<0 Then B=-B
FILLINGS5CBEAM
For I=1 To 4
S5(4,I)=0 : S5(I,4)=0
Next I
End If
End If

End Sub
```

```
Private Sub FILLINGS5CBEAM

'Row 1 Of S5.
S5(1,1)=A : S5(1,2)=B : S5(1,3)=-A
S5(1,4)=B
'Row 2.
S5(2,1)=B : S5(2,2)=D : S5(2,3)=-B
S5(2,4)=E
'Row 3.
S5(3,1)=-A : S5(3,2)=-B
S5(3,3)=A : S5(3,4)=-B
'Row 4.
S5(4,1)=B : S5(4,2)=E : S5(4,3)=-B
S5(4,4)=D

End Sub
```

Private Sub MEMBERMATS5CBEAM()

Fig 1
Bending stiffness EI=EII(P) and the member end numbers are L=LL(P) and H=HH(P), preceding page.
D1=X1(H)-X1(L) and
L1=Sqr(D1^2). (See page 23 .)
With L on the left and H on the right is
D1=X1(H)-X1(L)>0.
See next page for the case that L and H are exchanged, then is D1=X1(H)-X1(L)<0.

For each member P data NL(P) and NH(P) were put in.

NL(P)=0, member end L is not a hinge.
NL(P)=1, member end L is a hinge.
NH(P)=0, member end H is not a hinge.
NH(P)=1, member end H is a hinge.

a) Member P without hingy member ends.
If NL(P)=0 And NH(P)=0 Then

FLHY	A	B	-A	B	UVL		A=12*EI/L1^3
MLH	B	D	-B	E	URL		B= 6*EI/L1^2
FHLY	-A	-B	A	-B	UVH		D= 4*EI/L1
MHL	B	E	-B	D	URH		E= 2*EI/L1

NL(P)=0 NH(P)=0

The characters A, B, D and E get their value and with subroutine
FILLINGS5CBEAM placed in matrix S5.

b) and c) Member P with a hingy member end at L or a hingy member end at H.
Else If NL(P)=1 Or NH(P)=1

A	0	-A	B	A	B	-A	0	A= 3*EI/L1^3
0	0	0	0	B	D	-B	0	B= 3*EI/L1^2
-A	0	A	-B	-A	-B	A	0	D= 3*EI/L1
B	0	-B	D	0	0	0	0	

NL(P)=1 NH(P)=1

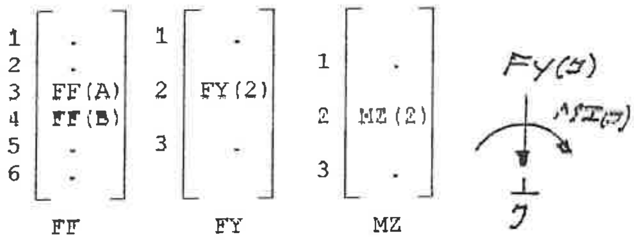
A, B and D get their value and are placed in S5. All sixteen elements of S5 have got a value but there are rows and columns of which the values are zero.
If NL(P)=1 Then
Row 2 and column 2 are filled with zeros.
Else If NH(P)=1 Then
Row 4 and column 4 are filled with zeros.

d) Both member ends are hinges.
ElseIf NL(P)=1 And NH(P)=1 Then

In that case are A=0 : B=0 : D=0 : E=0 so that all elements of S5 become zero.
End Sub

Private Sub FILLINGS5CBEAM()
All sixteen elements of S5 become their values with the characters A, B, D and E, after that eventual corrections are applied in subroutine MEMBERMATS5CBEAM

End Sub




```
     A=2*I-1         B=2*I
I=2  A=2*2-1=3       B=2*2=4
I=3  A=2*3-1=5       B=2*3=6
```

Fig.1.

```
Private Sub CBEAMMAINCALC()

'1. Composition of construction
'matrix CC with member
'matrices S5.
CONSTRMATCCCBEAM          page 21
'2. Elements of force vector FF.
'2a. Joint load forces FY(I) and
'joint load moments MZ(I).
N=2*N9
For I=1 To N9
A=2*I-1 : B=2*I
FF(A)=FY(I) : FF(B)=MZ(I)
PP(A)=PV(I) : PP(B)=PR(I)
UU(A)=UV(I) : UU(B)=UR(I)
SS(A)=SV(I) : SS(B)=SR(I)
Next I
```

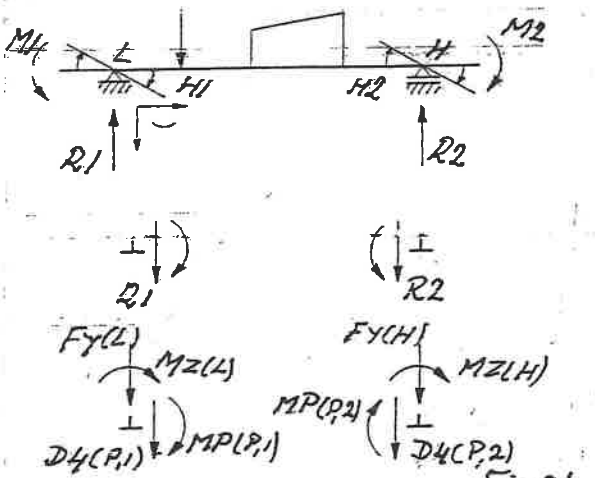


Fig.2b.

```
'2b. Primary forces and moments
'due to member loads perpendicular
'to the member axis.
For P=1 To P9 : L=LL(P) : H=HH(P)
EI=EII(P)
D1=X1(H)-X1(L)
L1=Sqr(D1^2)
If LE(P)=1 And RE(P)=1 Then
M1=0 : M2=0
BEAM1
ElseIf LE(P)=1 Or RE(P)=1 Then
M1=0 : M2=0 : M3=0 : M4=0
BEAM2
ElseIf LE(P)=0 And RE(P)=0 Then
BEAM3
End If
'primary moments and forces
M11(P)=M1 : R11(P)=R1
M22(P)=M2 : R22(P)=R2
```

Private Sub CBEAMMAINCALC()

With this subroutine the main calculation is carried out for continuous beams.
(And can also be used for simple beams on two supports.)
Construction matrix CC is formed with

1. CONSTRMATCCCBEAM in which the member stiffness matrices S5 are placed/inserted

2. Elements of force vector FF.
2a. The joint load forces FY(I) and the joint load moments MZ(I).

Fig.1.
With N9 joints and two displacements per joint, translation UV(I) and rotation UR(I), the number of equations is N=2*N9.
For each joint are by means of
A=2*I-1 : B=2*I
joint load force FY(I) and joint load moment MZ(I) placed in total vector FF.
Next PV(I) and PR(I) in total vector PP, UV(I) and UR(I) in UU, and SV(I) and SR(I) in SS.

2b. Primary forces and primary moments due to member loads perpendicular to the member/beam axis.

Fig.2a.
For each member P=1 To P9 the bending stiffness is set EI=EII(P) and are calculated
D1=X1(H)-X1(L) : L1=Sqr(D1^2)

With the beam axes system at member end L, for each member P are calculated the reactions R1 and R2, the reaction moments M1 and/or M2, whether or not existing, and the slope deflections H1 and H2, using subroutine
BEAM1 of page 1 , or
BEAM2 of page 4 , or
BEAM3 of page 7 .
On the joints act forces and moments as large as but opposite directed.
And then, see next page, becomes C=D1/L1. Not earlier because C is used in BEAM3.

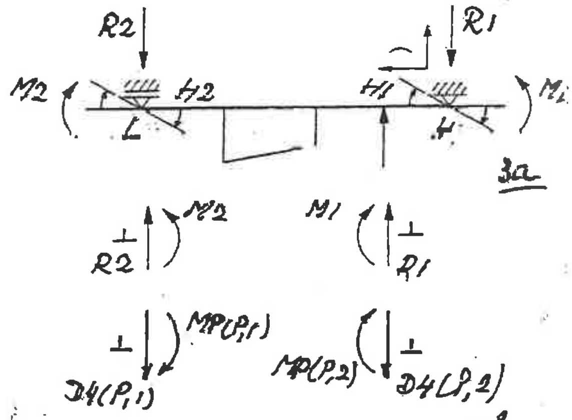
With BA(P)=L is indicated that the beam axes system is placed at member end L and in that case is C=D1/L1=+1 and can one write R1*C and RC*2.

Fig.2b.
On the joints act the primary forces D4(P,1) at L and D4(P,2) at H, and the primary moments MP(P,1) at L and MP(P,2) at H according to assumed directions
Then follow considering the assumed directions,

D4(P,1)=R1*C : D4(P,2)=R2*C
MP(P,1)=M1 : MP(P,2)=-M2.

Is one of both member ends a hinge, or are both member ends hinges, then the slope deflections H1 or/and H2 are used for the separatedly calculated slope deflections which are stored in

HE(P,1)=H1 : HE(P,2)=H2.




```
C=D1/L1
If BA(P)=L Then
D4(P,1)=R1*C : D4(P,2)=R2*C
MP(P,1)=M1  : MP(P,2)=-M2
HE(P,1)=H1  : HE(P,2)=H2
Else If BA(P)=H Then
D4(P,1)=-R2*C : D4(P,2)=-R1*C
MP(P,1)=-M2  : MP(P,2)=M1
HE(P,1)=H2  : HE(P,2)=H1
End If
Next P
```

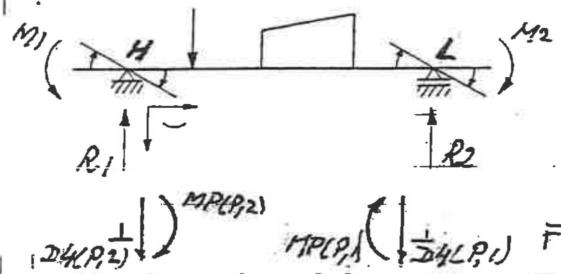
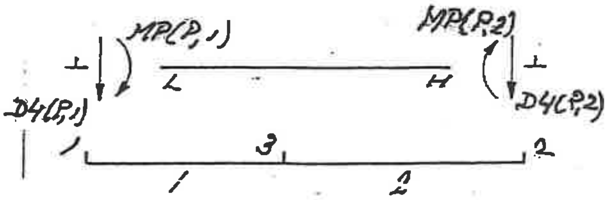


Fig.4.

```
'2c Alteration of force vector FF.
For I=1 To N9
A=2*I-1 : B=2*I
For P=1 To P9 : L=LL(P) : H=HH(P)
I I<=L Then
FF(A)=FF(A)+D4(P,1)
FF(B)=FF(B)+MP(P,1)
Else If I=H Then
FF(A)=FF(A)+D4(P,2)
FF(B)=FF(B)+MP(P,2)
End If
Next P
Next I
```



	FF(A)	D4(1,1)
	FF(B)	MP(1,1)
D4(2,1)	.	
MP(2,1)	.	
D4(1,2)	.	D4(2,2)
MP(1,2)	.	MP(2,2)

Fig.5.

Fig.3a en 3b.
Else If BA(P)=H Then
This time the beam axes system is placed at member end H.
Then are R1 at H and R2 at L directed downward.
The joint numbers are not exchanged so that also now C=D1/L1=+1 and can one write R1*C and R2*C.
Moment M1 at H also now to the right, and moment M2 at L also now to the left.
Further slope/angle H1 at H and slope/angle H2 at L also now to the right.

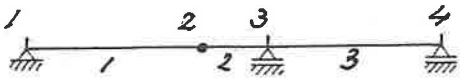
On the joints L and H act forces and moments as large as but opposite directed.
The direction of the primary force D4(P,1) at L is opposite directed to that of R2*C, and of the primary force D4(P,2) at H opposite to that of R1*C, so that
D4(P,1)=-R2*C : D4(P,2)=-R1*C.
And for the primary moments follow considering the directions
MP(P,1)=-M2 : MP(P,2)=M1 and for the slope deflections
HE(P,1)=H2 : HE(P,2)=H1.

Fig.4.
The load case of fig.2a but L and H are exchanged. Also now is BA(P)=H, so that
D4(P,1)=-R2*C at joint L. Is that correct?
On joint L acts R2 downward like D4(P,1).
C=D1/L1=-1 ! so D4(P,1)=R2 is correct.
D2(P,2)=-R1*C at joint H is correct as well.
C makes all go well.
Moments and slope deflections are also correct.
Note, always (P,1) at L, and (P,2) at H.

2c. Alteration of force vector FF.

Fig.5.
The assumed directions for the on the joints acting primary forces and moments are the same as those for the joint load forces and joint load moments. The primary forces and moments are added to the preceding values of the elements of vector FF.
For each joint I all members P=1 To P9 are checked if the member delivers on that joint I a primary force or moment.
As shown below for these three 'unregular' numbered joints and two members.

```
I=1   A=2*I-1=1    B=2*I=2
P=1   L=1   H=3    I=L=1    I<>H
      FF(A)=FF(A)+D4(P,1)    FF(1)=FF(1)+D4(1,1)
      FF(B)=FF(B)+MP(P,1)    FF(2)=FF(2)+MP(1,1)
P=2   L=2   H=3    I<>L     I<>H
I=2   A=2*2-1=3    B=2*2=4
P=1   L=1   H=3    I<>L     I<>H
P=2   L=2   H=3    I=L=2    I<>H
      FF(A)=FF(A)+D4(P,1)    FF(3)=FF(3)+D4(2,1)
      FF(B)=FF(B)+MP(P,1)    FF(4)=FF(4)+MP(2,1)
I=3   A=2*3-1=5    B=2*3=6
P=1   L=1   H=3    I<>L     I=H=3
      FF(A)=FF(A)+D4(P,2)    FF(5)=FF(5)+D4(1,2)
      FF(B)=FF(B)+MP(P,2)    FF(6)=FF(6)+MP(1,2)
P=2   L=2   H=3    I<>L     I=H=3
      FF(A)=FF(A)+D4(P,2)    FF(5)=FF(5)+D4(2,2)
      FF(B)=FF(B)+MP(P,2)    FF(6)=FF(6)+MP(2,2)
```



$$
\begin{array}{c}1\\2\\3\\4\\5\\6\\7\\8\end{array}
\begin{bmatrix} . & . & . & . & CC(1,5) & . & . \\ . & . & . & . & . & . & . \\ . & . & . & . & CC(K,5) & . & . \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ . & . & . & . & CC(8,5) & . & . \end{bmatrix}
\cdot
\begin{bmatrix} . \\ . \\ . \\ . \\ UU(5) \\ . \\ . \\ . \end{bmatrix}
=
\begin{bmatrix} FF(1) \\ . \\ FF(K) \\ . \\ . \\ . \\ . \\ FF(N) \end{bmatrix}
$$

CC UU FF

Fig.6.

```
'3 Alteration of force vector FF
'and concstruction matrix CC.
'3a Of FF in case of prescribed
'displacements <>0.
For I=1 To N
If UU(I)<>0 Then
For K=1 To N
FF(K)=FF(K)-CC(K,I)*UU(I)
Next K
End If
Next I
```

$$
\begin{array}{cccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \end{array}
$$

$$
\begin{bmatrix}
1 & 0 & 0 & \underline{0} & & & & \\
0 & . & . & \underline{0} & & & & \\
0 & . & . & \underline{0} & 0 & . & & \\
\underline{0} & \underline{0} & \underline{0} & \underline{0} & \underline{0} & \underline{0} & & \\
 & & 0 & \underline{0} & 1 & 0 & 0 & 0 \\
 & & . & \underline{0} & 0 & . & 0 & \\
 & & & & 0 & 0 & 1 & 0 \\
 & & & & 0 & . & 0 & .
\end{bmatrix}
\cdot
\begin{bmatrix} UU1 \\ . \\ . \\ -- \\ UU5 \\ . \\ UU7 \\ . \end{bmatrix}
=
\begin{bmatrix} UU1 \\ . \\ . \\ 0 \\ UU5 \\ . \\ UU7 \\ . \end{bmatrix}
$$

CC UU FF

```
'3b. Of FF and CC in case of pres-
'cribed displacements.
For I=1 To N
If PP(I)=1 Then
For J=1 To N
CC(I,J)=0 : CC(J,I)=0
Next J
CC(I,I)=1 : FF(I)=UU(I)
End If
Next I

'3c. Of FF and CC if the joint is
'a hinge.
For I=1 To N
If CC(I,I)=0 Then CC(I,I)=1 _
                          FF(I)=0
Next I

'3d. Of CC in case of springy/
'elastic supports.
For I=1 To N
If SS(I)>0 Then
CC(I,I)=CC(I,I)+SS(I)
End If
Next I
```

3. Alteration of force vector FF and construction matrix CC.
3a. Of FF in case of prescribed displacements <>0.

Fig.6.
Suppose that for joint 3 displacement UV(3) is prescribed and unequal to zero.
With A=2*I-1=2*3-1 is that UU(5) in total vector UU.
For I=1 To N is checked if there is a displacement UU(I)<>0. If so, then all elements of total vector FF must be lessened with CC(K,I)*UU(I).

If UU(I)=UU(5)<>0 with CC(K,5)*UU(5).
For K=1 To N
FF(K)=FF(K)-CC(K,I)*UU(I)
FF(1)=FF(1)-CC(1,5)*UU(5)
FF(2)=FF(2)-CC(2,5)*UU(5)
FF(3)=FF(3)-CC(3,5)*UU(5)
FF(4)=FF(4)-CC(4,5)*UU(5) and so on.

3b. Of FF and CC in case of prescribed displacements. (equal to zero and uneqal to zero as well)

Fig.7.
Is for a joint I=1 To N9 the vertical displacement UV(I) prescribed, then has been put in PP(I)=1.
Is for a joint I=1 To N9 the joint rotation prescribed then has been put in PR(I)=1.
PP(I) is with A=2*I-1, and PR(I) is with A=2*I placed in total vector PP.
Here are prescribed UV(1), UV(3) and UV(4), or, UU(1), UU(5) and UU(7).
For I=1 To N (=2*N9) is checked if a displacement is prescribed, thus if PP(I)=1.
Is PP(1)=1 then is UU(1), is UV(1), prescribed and the first row and first column of CC filled with zeros with CC(I,J)=0 and CC(J,I)=0.

I=1				
J=1	CC(I,J)=CC(1,1)=0	and	CC(J,I)=CC(1,1)=0
J=2	CC(1,2)=0	and	CC(2,1)=0
J=3	CC(1,3)=0	and	CC(3,1)=0

and so on.
After the diagonal element is set zero CC(1,1)=1 and gets FF(1) the value UU(1).
Similar for UU(5) and UU(7).

3c. Alteration of FF and CC if the joint is a hinge.

The stiffness matrices S5 of member 1 and 2 (see page 22) deliver the underlined zeros in matrix CC so that CC(4,4)=0. For I=1 To is checked if CC(I,I)=0. If so then become CC(I,I)=1 and FF(I)=0.
So here CC(4,4)=1 and FF(4)=0. After solution of the equations one will find UU(4)=0, the not existing rotation UR(2)=0.

3d. Of CC in case of springy supports.

If SS(I)>0 then a spring constant for a translation or rotation spring has been put in, which value is added to the concerning element on the main diagonal.

```
'4. Calculation of the unknown
'displcements UV(I) and UR(I).
For I=1 To N : BB(I)=FF(I)
For J-1 To N
AA(I,J)=CC(I,J)
Nont J
Next I          A x - b  is  C u - f

'The solution of N=2*N9
'equations.
GAUSS                page
For I=1 To N9
A=2*I-1 : B=2*I
UV(I)=XX(A) : UR(I)=XX(B)
UU(A)=XX(A) : UU(B)=XX(B)
Next I

'4b. Slope deflections separatedly
'calculated in case of hingy mem-
'ber ends.
For P=1 To P9 : L=LL(P) : H=HH(P)
D1=X1(H)-X1(L)
L1=Sqr(D1^2)

ZL=UV(L) : ZH=UV(H)
H6=(ZH-ZL)/L1

H7=1.5*(ZH-ZL)/L1     (next page)
```

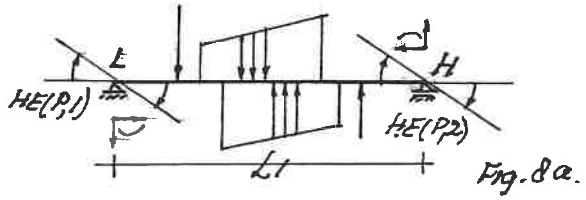


Fig.8a.

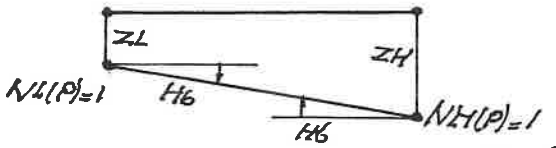


Fig.8b.

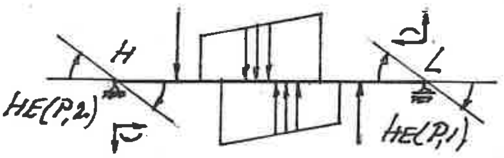


Fig.8c.

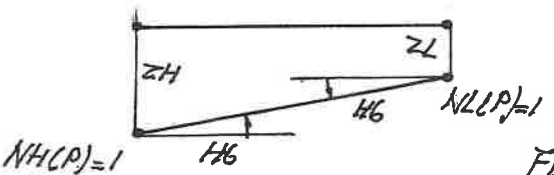


Fig.8d.

```
If NL(P)=1 And NH(P)=1 Then

If D1>0 Then _
HE(P,1)=HE(P,1)+H6 : _
HE(P,2)=HE(P,2)+H6

If D1<0 Then _
HE(P,1)=HE(P,1)-H6 : _
HE(P,2)=HE(P,2)-H6
```

4. Calculation of the unknown displacements, translation UV(I) and rotation UR(I).

On behalf of the solution of the equations with subroutine GAUSS (page) is vector BB filled with the elements of force vector FF, and matrix AA with the elements of construction matrix CC.
After solution of the unknowns XX() these are placed in the vectors UV and UR, and in total vector UU as shown here below.

	UU	UV	UR		XX
3	.	.		3	.
4	.		.	4	.
5	UU(A)	UV(3)		5	XX(A)
6	UU(B)		UR(3)	6	XX(B)
7	.	.		7	.
8	.		.	8	.

For example joint I=3. A=2*I-1=5 B=2*I=6
UV(I)=XX(A) UV(3)=XX(5) UR(I)=XX(B) UR(3)=XX(6)
UU(A)=XX(A) UU(5)=XX(5) UU(B)=XX(B) UU(6)=XX(6)

4b. Slope defelections separatedly to be calculated in case of hingy member ends.

Fig.8a.
For P=1 To P9 : L=LL(P) : H=HH(P)
D1=X1(H)-X1(L)
L1=Sqr(D1^2)
For this case is D1>0.
When calculating the primary forces and moments, the beam axis system placed at L or at H, the slope deflections HE(P,1) at L, and HE(P,2) at H are also calculated, these are slopes due to member loads alone.

Fig.8b.
If Both member ends are hinges,
If NL(P)=`And NH(P)=1 Then
arise at the member ends slopes H6 due to the displacements alone.
With ZL=UV(L) and ZH=UV(H), and assumed that ZH is larger than ZV, follows
H6=(ZH-ZL)/L1 to the right.

```
If D1>0 Then _
HE(P,1)=HE(P,1)+H6 : _
HE(P,2)=HE(P,2)+H6
```

The underscores makes of the three lines one statement. Mostly e.g. next way is chosen

```
If D1=0 Then
HE(P,1)=HE(P,1)+H6 : HE(P,2=HE(P,2)+H6
End If
```

Fig.8c and 8d.
Now the member end numbers L and H are exchanged, then becomes D1<0. With the assumption that ZH is larger than ZL is also now H6=(ZH-ZL)/L1 but not to the right but to the left, contrary to the assumption for HE(P,1) and HE(P,2). Then follows
AA

```
If D1>0 Then _
HE(P,1)=HE(P,1)-H6 : HE(P,2)=HE(P,2)-H6
```

On the left in three lines because the column width made for the text was not large enough.

```
ElseIf NL(P)=1 Then
If D1>0 Then
HE(P,1)=HE(P,1)+H7-0.5*UR(H)
If D1<0 Then
HE(P,1)=HE(P,1)-H7-0.5*UR(H)
```

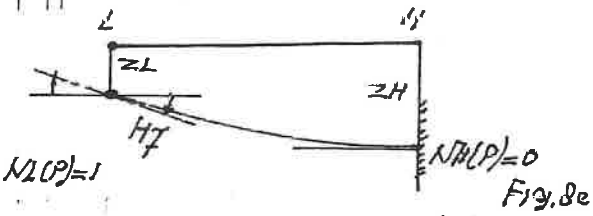


Fig.8e

Fig.8f

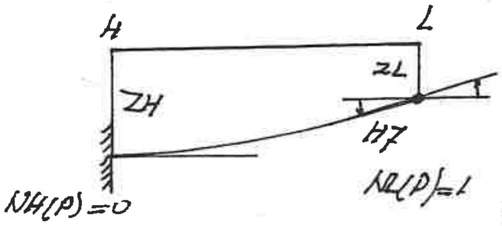


Fig.8g.

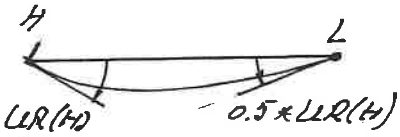


Fig.8h.

```
ElseIf NH(P)=1 Then
If D1>0 Then
HE(P,2)=HE(P,2)+H7-0.5*UR(L)
If D1<0 Then
HE(P,2)=HE(P,2)-H7-0.5*UR(L)
End If
Next P
```

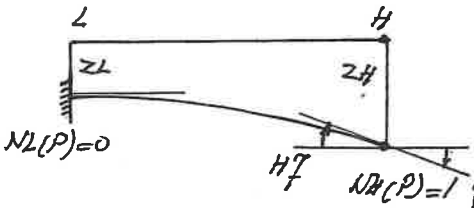


Fig.8i.

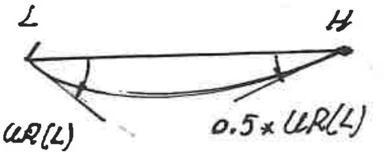


Fig.8j

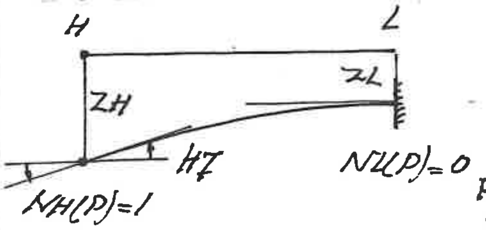


Fig.8k.

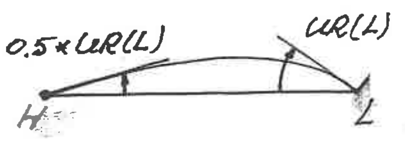


Fig.8l.

If both beam ends are not hinges then there are two more possibilities left.

ElseIf NL(P)=1 Then

Member end L of the beam is a hinge, and member end H is connected with a real joint. One could have written also ElseIf NL(P)=1 and NH(P)=0 Then but not necessary after If NL(P)=1 And NH(P)=1 Then.

Fig.8e and 8f.
If D1>0 Then HE(P,1)=HE(P,1)+H7-0.5*UR(H)

The effect of the displacements ZL and ZH on the slope at L to be calculated separately can be seen as the sum of two cases.

Fig.8e.
Before the displacements of member end L and joint H, is member end H, joint H is held, clamped. After the displacements take place the figure drawn arises with slope H7 at L directed to the right. The magnitude of H7 is, see page with the formulas,
H7=1.5*(ZH-ZL)/L1 already written on the preceding page.

Fig.8f.
Without the displacements ZL and ZH, the beam is bent by rotation of joint H, assumption to the right. The beam bends like drawn and at member end L arises a slope which magnitude is half of that rotation UR(H), 0.5*UR(H) and directed to the left as the figure shows.

Taking into account the assumption for HE(P,1) to the right follows, (P,1) is (L,H),
HE(P,1)=HE(P,1)+H7-0.5*UR(H).

Fig.8g and 8h.
If D1<0 Then HE(P,1)=HE(P,1)-H7-0.5*UR(H)
Mdember end L is also now a hinge but L and H are exchanged.
Due to the displacements ZL and ZH arises at L a slope H7 directed to the left of which the magnitude is 1.5*(ZH-ZL)/L1 like before.
Rotation UR(H) causes also now a slope at L 0.5*UR(H) to the left. With HE(P,1) to the right follows the eqution for D1<0 just written.

ElseIf NH(P)=1 Then

Now member end H is a hinge and member end L is rigidly connected with real joint L.

Fig.i and j.
If D1>0 Then HE(P,2)=HE(P,2)+H7-0.5*UR(L)
Due to ZL and ZH arises a slope H7 to the right and due to the rotation UR(L) of joint L arises a slope of 0.5*UR(L) at member end H.

Fig.k and l.
If D1<0 Then HE(P,2)=HE(P,2)-H7-0.5*UR(L)
The same procedure, now slope H7 is directed to the left.
(Slope H7 arises due to the assumed directions of ZL and ZH downward, and! the assumption that ZH is larger than ZL.)

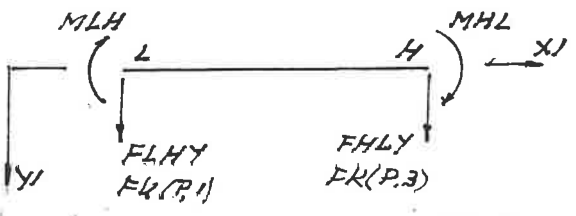


Fig.9a

```
'5. Calculation of the member end
'forces w.r.t. the construction
'axes system X-Y.
'5a. Deuto the displacements
'alone.
For P=1 To P9 : L=LL(P) : H=HH(P)
EI=EII(P)
MEMBERMATS5CBEAM
TT(1)=2*L-1 : TT(2)=2*L
TT(3)=2*H-1 : TT(4)=2*H
For I=1 To 4 : FK(P,I)=0
For J=1 To 4 : A=TT(J)
FK(P,I)=FK(P,I)+S5(I,J)*UU(A)
Next J
Next I

'5b. Due to displacements and
'member/beam loads perpendicular
'to the member/beam axis..
D6(P,1)=FK(P,1)-D4(P,1)
MF(P,1)=FK(P,2)-MP(P,1)
D6(P,2)=FK(P,3)-D4(P,2)
MF(P,2)=FK(P,4)-MP(P,2)
Next P

'6. Calculation of the joint 'for-
'ces' KV(I) and KM(I).
'6a. Due to the displacements
'alone.
CONSTRMATCCCBEAM
For I=1 To N9
A=2*I-1 : B=2*I
KV(I)=0 : KM(I)=0
For J=1 To N
KV(I)=KV(I)+CC(A,J)*UU(J)
KM(I)=KM(I)+CC(B,J)*UU(J)
Next J
```

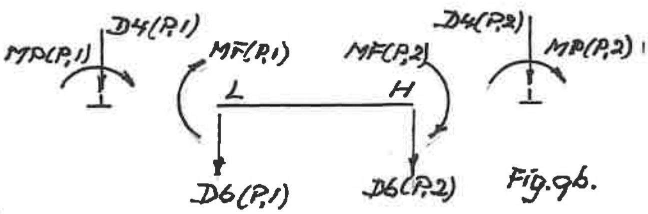


Fig.9b.

.	. . . .		.
.	. . . .		UU(J)
KV(I)	. . CC(B,J) . . .		.
KM(I)	. . CC(B,J) . . .		.
.	. . . .		.
.	. . . .		.

Fig.10a.

5. Calculation of the member end forces w.r.t. to the construction axes system X-Y.
5a. Due to the displacements alone.

Fig.9a.
The relation between member end forces and displacements is f = S5 u.

f		S5	UU	u
FLHY	FK(P,1)	11 12 13 14	UU(A)	UV(L)
MLH	FK(P,2)	21 22 23 24	UU(A)	UR(L)
FHLY	FK(P,3)	31 32 33 34	UU(A)	UV(H)
MHL	FK(P,4)	41 42 43 44	UU(A)	UR(L)

For member P the bending stiffness is Ei=EII(P).
With subroutine
MEMBERMATS5CBEAM (page 22)
member stiffness matrix S5 is formed.

Each of the four member end forces and member end moments FK(P,I) is equal a row of stiffness matrix S5 times column u.

By means of UU(J) for J=1 To 4, for each member the four necessary displacements are taken out of total vector UU, but before that TT(1) to TT(4) are determined with the member end numbers L and H.

5b. Due to displacements and member loads perpendicular to the member axis.

Fig.9b.
The direction of the on the joints acting primary forces D4(P,1) and D4(P,2) is assumed downward. On the member ends act forces as large as but opposite directed, thus upward. The direction of the on the joints acting primary moments MP(P,1) and MP(P,2) is assumed to the right, thus on the member ends to the left.

The direction of the final member end forces D6(P,1) at L and D6(P,2) at H, is assumed downward. Then become
D6(P,1)=FK(P,1)-D4(P,1) and
D6(P,2)=FK(P,3)-D4(P,2).

The direction of the final member end moments MF(P,1) at L and MF(P,2) at H, is assumed to the right. Then follow taking into account the assumed directions
MF(P,1)=FK(P,2)-MP(P,1) and
MF(P,2)=FK(P,4)-MP(P,2).

6. Calculation of the joint forces KV(I) and the joint moments KM(I).
6a. Due to the displacements alone.

Fig.10a.
The necessary original construction matrix CC is formed with subroutine
CONSTRMATCCCBEAM.
Each joint force and each joint moment is equal to a row of CC times total vector UU.

KV(I) with row number A and KM(I) with row number B.

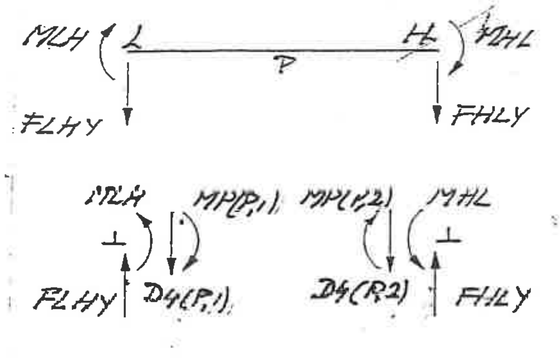


Fig.10b.

```
'6b. Due to displacements and
'member loads perpendicular to the
'member axis.
For P=1 To P9 : L=LL(P) : H=HH(P)
If I=L Then
KV(I)=KV(I)-D4(P,1)
KM(I)=KM(I)-MP(P,1)
Else If I=H Then
KV(I)=KV(I)-D4(P,2)
KM(I)=KM(I)-MP(P,2)
End If
Next P
Next I
```

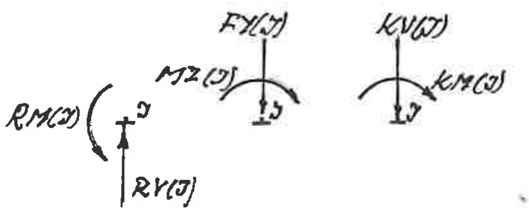


Fig.11.

```
'7. Calculation of the reactions.
For I=1 To N9
If SV(I)>0 Then
RV(I)=SV(I)*UV(I)
Else
RV(I)=-KV(I)+FY(I)
End If
If SR(I)>0 Then
RM(I)=SR(I)*UR(I)
Else
RM(I)=-KM(I)+MZ(I)
End If
Next I

End Sub
```

6b. Due to displacements and member loads perpendicular to the member axis.

Fig.10b.
The on the member ends acting member end forces FLHY and FHLY are assumed to be directed downward, on the joints act forces as large as but opposite directed, thus upward. Only therefore joint force KV(I) was asumed upward.

The on the me mber ends acting member end moments MLH and MHL are assumed to the right, on the joints act moments as large as but directed to the left. Only therefore the direction of joint moment KM(I) was assumed to the left.

The on the joints acting primary forces D4(P,1) and D4(P,2) are assumed to be dircted downward, and the on the joints acting primary moments are assumed to be directed to the right.

For each joint I=1 To N9 (see preceding page) is checked at all members P=1 To P9 if member P delivers on joint I=L a primary force D4(P,1) and/or a primary moment MP(P,1). Taking into account the assumed directions then follows
If I=L Then
KV(I)=KV(I)-D4(P,1)
KM(I)=KM(I)-MP(P,1)
Or member P delivers on joint I+H a primary force D4(P,2) and/or a primary moment MP(P,2).

Else If I=H Then
KV(I)=KV(I)-D4(P,2)
KM(I)=KM(I)-MP(P,2)
End If
And the next member with Next P and after member P=P9 follows the next joint with Next I.

7. Calculation of the reactions.
Fig.11.
The vertical reaction is mostly directed upward, only therefore is assumed that reaction RV(I) is directed upward. And the direction of the moment reaction is, well, assumed to the left, (a choice) because KM(I) and RM(I) have the same direction, like also KV(I) and RV(I) have the same direction.

Is SV(I)>0 then there is a vertical translation spring and arises with an assumed downward displacement UV(I) an upward directed spring reaction VKV=SV(I)*UV(I). Then is reaction RV(I)=SV(I)*UV(I).
If there is no hinge, SV(I)=0 has been put in, then follows RV(I) with Σ vert. joint I =0.
RV(I)+KV(I)-FY(I)=0 ⇒ RV(I)=-KV(I)+FY(I)

If SR(I)>0 then there is a rotation spring and arises, with an assumed direction UR(I) to the right, a spring reaction moment VKM=SR(I)*UR(I) to the left. Then the reaction moment is RM(I)=SR(I)*UR(I).
If there is no rotation spring, then follows RM(I) with Σ mom. joint I=0.
RM(I)+KM(I)-MZ(I)=0 ⇒ RM(I)=-KM(I)+MZ(I)
End of the 'seven main steps'.

End Sub.

4.11. Private Sub CBDRAWT5()

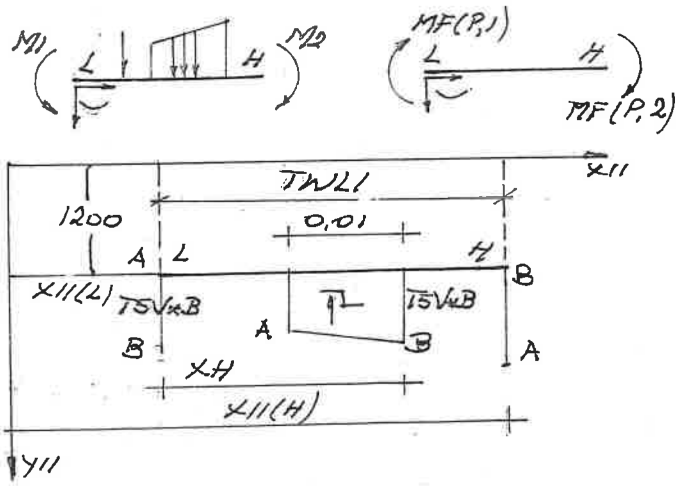
```
Private Sub CBDRAWT5()
T5MAXX=0
'
For P=1 To P9: L=LL(P) : H=HH(P)
D1=X1(H)-X1(L)
L1=Sqr(D1^2) : L11(P)=L1
C=D1/L1
'
If BA(P)=L Then
M1=-MF(P,1) : M2=MF(P,2)
ElseIf BA(P)=H Then
M1=-MF(P,2) : M2=MF(P,1)
End If
'
T5MAX                    page
If Abs(T5MAXX)<Abs(TMAX) Then
T5MAXX=TMAX : XTT=XT : PT=P
End If
Next P
If Format(T5MAXX,"0")=0 Then _
T5MAXX=1
B=450/Abs(T5MAXX)
'-------------------
For P=1 To P9 : L=LL(P) : H=HH(P)
D1=X1(H)-X1(L)
L1=Sqr(D1^2) : L11(P)=L1
C=D1/L1
'
D11=X11(H)-X11(L)
TWL1=Sqr(D11^2)
'
If BA(P)=L Then
M1=-MF(P,1) : M2=MF(P,2)
'
XA=X11(L) : YA=Y11(L)
X=0 : T5M5XX              page 9
T5V=T5*C
XB=X11(L)
YB=Y11(L)+T5V*B
LINEXAYAXBYB       'PRP=0 or PRP=1
XA=XB : YA=YB
'
For X=0.01 To L1+0.01 Step 0.01
XH=X*C
T5M5XX
T5V=T5*C
XB=X11(L)+XH*(TWL1/L1)
YB=Y11(L)+T5V*B
LINEXAYAXBYB       page 42
If X>=L1 Then
XA=XB : YA=YB
XB=X11(L)+L1*C*(TWL1/L1)
YB=Y11(L)
LINEXAYAXBYB
Exit For    'to avoid 'problems'
End If

XA=XB : YA=YB
Next X
```

If X>=L1 Then
for the last line to draw from A to B, follows for point B on the zero line, XB=X11(L)+L1*C*(TWL1/L1), so having C a positive value XB gets the same value as X11(H).
(Why using C? When dealing with plane frames C=D1/L1 and also S=D2/L1 will be used to determine point B, and A.)

With this subroutine the tranverse force diagrams for all beams of a continous beam are drawn. See page   for drawing the diagram for a simple beam.
First the largest appearing transverse force T5MAXX will be calculated, start value T5MAXX=0, using subroutine T5MAX, see next page. Then M1 and M2 are asked and they are the calculated beam end moments MF(P,1) at beam end L, and MF(P,2) at beam end H.
Coordinates X1() are used given in meters, the displacement is found in /EI.
<u>If BA(P)=L Then</u>
<u>M1=-MF(P,1) : M2=MF(P,2)</u> which is correct for both cases, L on the left or on the right of the beam.
<u>ElseIf BA(P)=H Then</u>   See fig.
<u>M1=-MF(P,2) : M2=MF(P,1)</u> for H on the right as well on the left of the beam.
After the largest is found then becomes B=450/Abs(T5MAXX), the largest transverse force drawn will have a length of 450 twips.
A twip is (2,54/1440)=0,00176 cm. 567 tw= 1 cm
But, If Format(T5MAXX,"0")=0 Then T5MAXX=1.

Next the transverse force diagram for each beam P=1 To P9 is drawn.
C=D1/L1 which can be positive or negative.
Now the already determinated coordinates X11() are used. The length of a beam in twips follows with
D11=X11(H)-X11(L), then
TWL1=Sqr(D11^2).   (also is C=D11/TWL1)

<u>If BA(P)=L Then</u>



First T5 becomes T5V, after calculation of T5 for X=0 becomes <u>T5V=T5*C</u>. In this case is C positive, X1(H)-X1(L)>0, so T5V has a positive value, it is plotted below the zero line, YB=1500<u>+T5V*B</u>. After that follows
For X=0 To L1+0.01 Step 0.01
First XH=X*C, in meters!, with a positive C measured from X11(L) to the right, then subroutine T5M5XX and then each time after that T5V=T5*C, and then XB=X11(L)+XH*(TWL1/L1).

```
ElseIf BA(P)=H Then
M1=-MF(P,2) : M2=MF(P,1)
'
XA=X11(H) : YA=Y11(H)    'YA=1200
X=0 : T5M5XX
T5V=T5*C
XB=X11(H)
YB=Y11(H)-T5V*B
LINEXAYAXBYB
XA=XB : YA=YB

For X=0.01 To L1+0.01 Step 0.01
XH=X*C
T5M5XX
T5V=T5*C

XB=X11(H)-XH*(TWL1/L1)
YB=Y11(H)-T5V*B
LINEXAYAXBYB

If X>=L1 Then
XA=XB : YA=YB
XB=X11(H)-L1*C*(TWL1/L1)
YB=Y11(H)
LINEXAYAXBYB
Exit For
End If

XA=XB : YA=YB
Next X
End If
Next P

End Sub
```

With subroutine T5MAX the largest transverse force TMAX for a beam P is calculated using subroutine T5M5XX for each X, by comparing the absolute values,
If Abs(TMAX)<Abs(T5) Then TMAX=T5.
And distance X is stored with XT=X.

```
Private Sub T5MAX()
TMAX=0
For X=0 To L1+0.01 Step 0.01
T5M5XX                'see page 9
If Abs(TMAX)<Abs(T5) Then
TMAX=T5 : XT=X
End If
Next X
End Sub
```

After that, see the preceding page, the largest of all, Abs(T5MAXX) is compared with the largest Abs(TMAX)of the current beam. If so then the distance XT for that beam is stored with XTT=XT,and the current beam with PT=P.

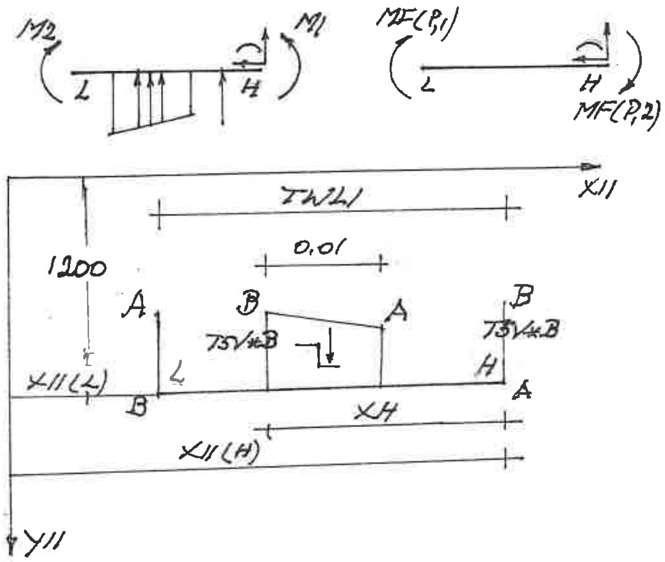
```
If Abs(T5MAXX)<Abs(TMAX) Then
T5MAXX=TMAX : XTT=XT : PT=P
End If
```

And after Next P, the last beam, follows B=450/Abs(TMAXX). Every transverse force is multiplied by B. The largest 'distance' to be plotted is 450 twips, that is (450/1440)*2,54= 0,8 cm.

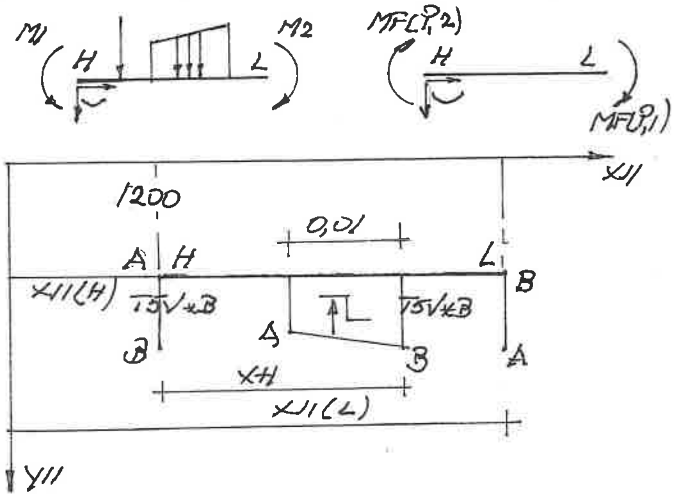
That was BA(P)=L with X1(H)>X1(L), the case with X1(H)<X1(L) is here omitted.

ElseIf BA(P)=H Then

The bam axis system at the beam end with the highest member end number H, also two possibilities when exchanging L and H. For both cases is C=D1/L1, already calculated, and are, see the figures below,
M1=-MF(P,2) : M2=MF(P,1).
Fig.



C=D1/L1 is positive, X1(H)-X1(L)>0.
Drawing starts now at H on the right with XA=X11(H). The assumed T5, becomeing T5V=T5*C is plotted above the zero line, C is pos. thus YB=1500-T5V*B, a minus sign to get point B.
Then for each X is XH=X*C, XH is pos., to get point B is XB=X11(H)-XH*(TWL1/L1), with the minus sign from H on the right to the left, correct.
And the last point B for X>=L1 becomes XB=X11(H)-L1*C*(TWL1/L1), with C=+1 that is from H over L1 to the left.
Fig.

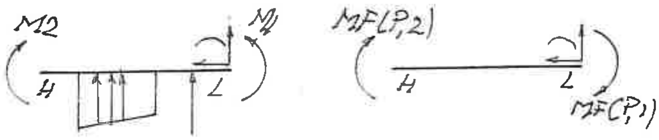


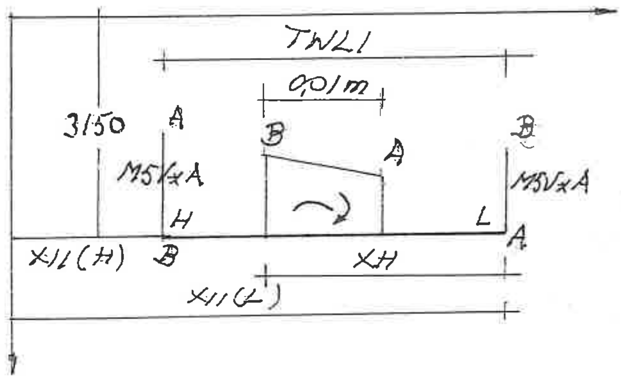
Now H on the left, L on the right, C is negative. The negative C and the minus signs in the formulas gives the correct values, drawing lines like on the preceding page.

```
Private Sub CBDRAWM5()
M5MAXX=0
'
For P=1 To P9: L=LL(P) : H=HH(P)
D1=X1(H)-X1(L)
L1=Sqr(D1^2) : L11(P)=L1
C=D1/L1
'
If BA(P)=L Then
M1=-MF(P,1) : M2=MF(P,2)
ElseIf BA(P)=H Then
M1=-MF(P,2) : M2=MF(P,1)
End If
'
M5MAX
If Abs(M5MAXX)<Abs(MMAX) Then
M5MAXX=MMAX : XT=X : PT=P
End If
Next P
If Format(M5MAXX,"0")=0 Then _
M5MAXX=1
A=450/Abs(M5MAXX)
'-------------------
For P=1 To P9 : L=LL(P) : H=HH(P)
D1=X1(H)-X1(L)
L1=Sqr(D1^2) : L11(P)=L1
C=D1/L1
'
D11=X11(H)-X11(L)
TWL1=Sqr(D11^2)
'
If BA(P)=L Then
M1=-MF(P,1) : M2=MF(P,2)
'
XA=X11(L) : YA=Y11(L)
X=0 : T5M5XX
M5V=M5*C
XB=X11(L)
YB=Y11(L)+M5V*A
LINEXAYAXBYB
XA=XB : YA=YB
'
For X=0.01 To L1+0.01 Step 0.01
XH=X*C
T5M5XX
M5V=M5*C
XB=X11(L)+XH*(TWL1/L1)
YB=Y11(L)+M5V*A
LINEXAYAXBYB
If X>=L1 Then
XA=XB : YA=YB
XB=X11(L)+L1*C*(TWL1/L1)
YB=Y11(L)
LINEXAYAXBYB
Exit For     'to avoid 'problems'
End If
XA=XB : YA=YB
Next X

ElseIf BA(P)=H Then
M1=-MF(P,2) : M2=MF(P,1)
'
XA=X11(H) : YA=Y11(H)
X=0 : T5M5XX
M5V=M5*C
XB=X11(H)
YB=Y11(H)-M5V*A
LINEXAYAXBYB
XA=XB : YA=YB
```

4.12. Private Sub CBDRAWM5()

As done for the simple beam, page 30, drawing the bending moment diagram is similar to that of the transverse diagram. The figure below shows the second case for BA(P)=L, omitted on page . T5 becomes M5, 1200 becomes 3150, and B becomes A, T5V*B becomes M5V*A, etc.



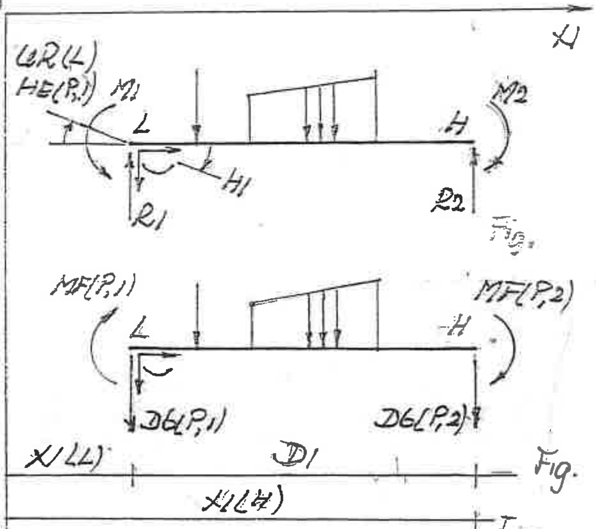


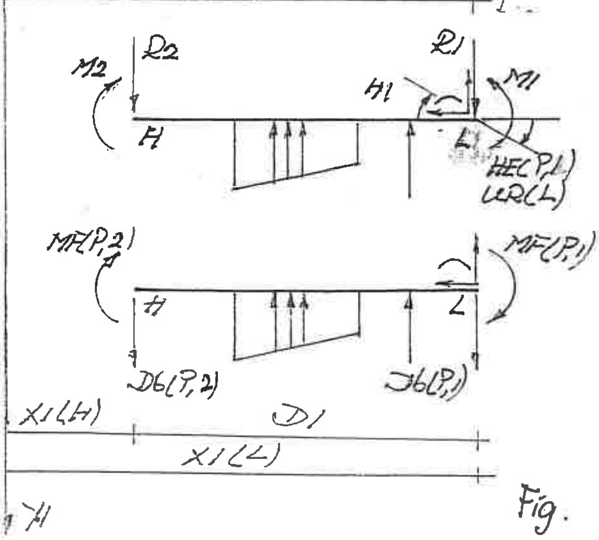

```
For X=0 To L1+0.01 Step 0.01
XH=X*C
T5M5XX
M5V=M5*C

XB=X11(H)-XH*(TWL1/L1)
YB=Y11(H)-M5V*A
LINEXAYAXBYB

If X>=L1 Then
XA=XB : YA=YB
XB=X11(H)-L1*C*(TWL1/L1)
YB=Y11(H)
LINEXAYAXBYB
Exit For
End If

XA=XB : YA=YB
Next X
End If
Next P

End Sub
```

With subroutine MMAXM5, see page 14, NM values for maximum moments and zero points MMAX(P,I) are calculated. The largest for a beam is MMAX which will be compared with the largest of all M5MAXX.

```
Private Sub M5MAX()
'calculation of the largest M5
MMAX=0
MMAXM5
For I=1 To NM
If Abs(MMAXX(P,I)>Abs(MMAX) Then
MMAX=MMAXX(P,I) : X=LM(P,I)
End If
Next I
End Sub
```

```
Private Sub CBDRAWELCURVE()
Z8MAXX=0
'
For P=1 To P9 : L=LL(P) : H=HH(P)
EI=EII(P) : D1=X1(H)-X1(L)
L1=Sqr(D1^2) : L11(P)=L1 : C=D1/L1

If BA(P)=L Then
If NL(P)=1 Then H1=HE(P,1)
If NL(P)=0 Then H1=UR(L)
R2=-D6(P,2)*C : M2=MF(P,2)
STZ8=UV(L)*C        'see page
ElseIf BA(P)=H Then
If NH(P)=1 Then H1=HE(P,2)
If NH(P)=0 Then H1=UR(H)
R2=D6(P,1)*C : M2=MF(P,1)
STZ8=-UV(H)*C       'expl. page
End If
'
ZMAXZ8                        'page 18
ZZMAXX(P)=ZMAXX(P,NZ)
XZ(P)=LZ(P,NZ)        'see page

ZMAX=Abs(ZMAXX(P,NZ))
XT=LZ(P,NZ)
If ZMAX>=Z8MAXX Then
Z8MAXX=ZMAX : XTT=XT : PT=P
End If
Next P
```





4.13. Private Sub CBFRAWELCURVE()

The largest displacement of all beams will be calculated to determine the scale of the curve to be printed. Before Z8MAXX=0.
For each beam P the maximum displacement will be calculate with subroutine ZMAXZ8 page 18 , using subroutine H8Z8XX of page 15 .

If BA(P)=L Then

The beam axis syatem is placed at beam end L.

The first possibility with L at the left, X1(L) is smaller than X1(H), then D1=X1(H)-X1(L) is positive, so is C=D1/L1.
To calculate displacements Z8 subroutine H8Z8XX is used, then are needed slope H1 at L, and R2 and M2 at the other end of the beam H.
The beam end forces are D6(P,1) and D6(P,2), both assumed to be directed downward, and the beam end moments are MF(P,1) and MF(P,2).
If NL(P)=1 then beam end L is a hinge and the seperately calculated angle is HE(P,1) which has the same assumed direction as angle H1, thus H1=HE(P,1).
If NL(P)=0 then beam end L is considered to be a real joint, the calculated joint rotation is UR(L) assumed to the right as well, and thus H1=UR(L).
The assumed direction of D6(P,2) is opposite to that of R2, therefore R2=-D6(P,2). And with C follows R2=-D6(P,2)*C, that is the same because C is positive.
M2 and MF(P,2) have same assumed directions, so M2=MF(P,2).

L and H are exchanged. Now D1=X1(H)-X1(L) is negative. For H1 and M2 the same results.
Also R2=-D6(P,2)*C, C is negative, then R2 gets an assumed positive value, that is correct because the figure shows that R2 and D6(P,2) have the same direction.

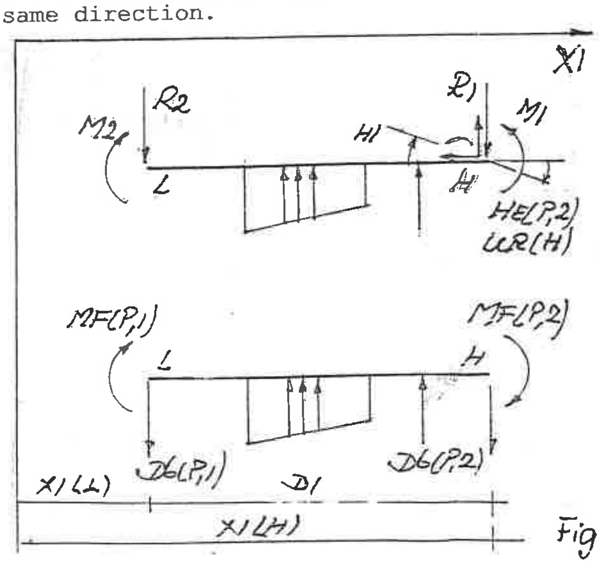


Fig.

If BA(P)=H Then
Fig.
One of both possibilities for. The same use of arguments leads to the printed results after BA(P)=H Then.

```
If Format(Z8MAXX,"0")=0 Then _
Z8MAXX=1
A=450/Z8MAXX

For I=1 To N9
Y11(I)=Y11(I)+UV(I)*A
Next I
'
'drawing the elastic curve
For P=1 To P9 : L=LL(P) : H=HH(P)
EI=EII(P)
D1=X1(H)-X1(L)
L1=Sqr(D1^2) : L11(P)=L1
C=D1/L1
'
D11=X11(H)-X11(L)
TWL1=Sqr(D11^2)
'
If BA(P)=L Then
If NL(P)=1 Then H1=HE(P,1)
If NL(P)=0 Then H1=UR(L)
R2=-D6(P,2)*C : M2=MF(P,2)
End If
If BA(P)=H Then
If NH(P)=1 Then H1=HE(P,2)
If NH(P)=0 Then H1=UR(H)
R2=D6(P,1)*C : M2=MF(P,1)
End If
'
If BA(P)=L Then XA=X11(L) : _
                YA=Y11(L)
If BA(P)=H Then XA=X11(H) : _
                YA=Y11(H)
'
A=450/Z8MAXX    'see rem. below
'
For X=0.01 To L1+0.01 Step 0.01
XH=X*C

STZ8=0
H8Z8XX
Z8V=Z8*C
'
If BA(P)=L Then
XB=X11(L)+XH*(TWL1/L1)
YB=Y11(L)+Z8V*A

ElseIf BA(P)=H Then
XB=X11(H)-XH*(TWL1/L1)
YB=Y11(H)-Z8V*A
End If
'
LINEXAYAXBYB      'PRP=0 or PRP=1
XA=XB : YA=YB
Next X

Next P
End Sub
```

page 15

A=450/Z8MAXX, before Z8MAXX was made Z8MAXX=1 in case it might be almost zero.
This was also done with TMAXX and M5MAXX.
But will/can one of the three have a value like 34822490087E-15?
Anyhow, just Format(...,"0") to round to exact zero to avoid 'problems'.

Drawing the elastic curve.

Before drawing the curve joint displacements UV(I) are prepared for the curve to be printed on the form with
Y11(I)=Y11(I)+UV(I)*A. (Or else, next page.)
These new coordinates of the joints are the start and end values of the curve for the beams For P=1 To P9.

Fig.
Again C=D1/L1 is used. And with the form coordinates X11() the length TWL1 in twips of each beam is calculated.
Again H1, R2 and M2 are depending on the place of the beam axis system and determined like on the preceding page.
And the starting point A to draw the curve depends on BA(P), not necessary but seperately written
If BA(P)=L Then XA=X11(L) : YA=Y11(L) and
If BA(P)=H Then XA=X11(H) : YA=Y11(L).

A=450/Z8MAXX one more time... to be sure... A could have gotten another value 'in between'...

For BA(P)=L and BA(P)=H the distance XH=X*C, X itself has a positive value. After calculation of Z8 with subroutine H8Z8XX, but first STZ8=0, becomes Z8V=Z8*C.

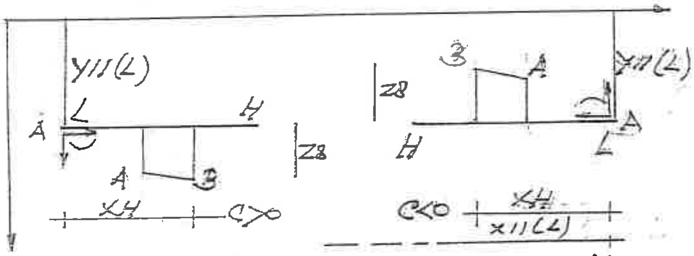


Fig.

If BA(P)=L Then
Fig.
XB=X11(**L**)+XH*(TWL1/L1)
YB=Y11(**L**)+Z8V*A
C>0, XH and Z8V are positive, then XH*(TWL1/L1) is added to X11(L), and
Z8V*A is added to Y11(L).
C<0, XH and Z8V are negative, then XH*(TWL1/L1) is subtracted from X11(L), and
Z8V subtracted from Y11(L).

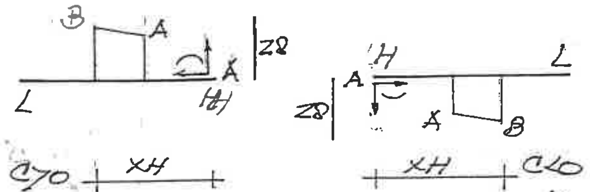


Fig.

ElseIf BA(P)=H Then
Fig.
XB=X11(**H**)-XH*(TWL1/L1)
YB=Y11(**H**)-Z8V*A
C>0, XH and Z8V are positive, then XH*(TWL1/L1) is subt#racted from X11(H), and
Z8V*A subtracted from Y11(H).
C<0, XH and Z8V are negative, then XH*(TWL1/L1) is added to X11(H), and
Z8V*A added to Y11(H). (minus*minus=plus)

```
....... (of page 33 )
If BA(P)=L Then
If NL(P)=1 Then H1=HE(P,1)
If NL(P)=0 Then H1=UR(L)
R2=-D6(P,2)*C : M2=MF(P,2)
STZ8=UV(L)*C
ElseIf BA(P)=H Then
If NL(P)=1 Then H1=HE(P,2)
If NL(P)=0 Then H1=UR(H)
R2=D6(P,1)*C : M2=MF(P,1)
STZ8=-UV(H)*C
End If
'
ZMAXZ8                        'page 18
ZZMAXX(P)=ZMAXX(P,NZ)
XZ(P)=LZ(P,NZ)          'see page

ZMAX=Abs(ZMAXX(P,NZ))
XT=LZ(P,NZ)
If ZMAX>=Z8MAXX Then
Z8MAXX=ZMAX : XTT=XT : PT=P
End If
Next P
.......
```

```
....... end of ZMAXZ8, page
ZMAX=0
For I=1 To NZ
If Abs(ZMAXX(P,I)>Abs(ZMAX) Then
ZMAX=ZMAXX(P,I) : X=LZ(P,I)
End If
Next I
NZ=NZ+1
ZMAXX(P,NZ)=ZMAX : LZ(P,NZ)=X
NZZ(P)=NZ
End Sub
```

For each beam P the NMM(P) bending moments when the transverse force is about zero and when the moment itself is about zero,

```
.......
NM=NM+1 : NMM(P)=NM
MMAXX(P,NM)=M5 : LM(P,NM)=X
.......
```

When clicking on caption M5MAXZERO these values are printed for each beam P.

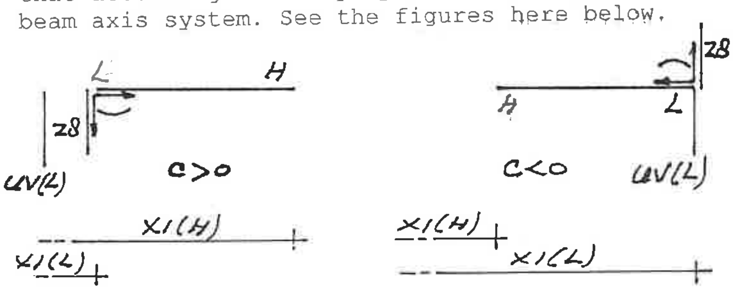
```
Private Sub LM5MAXZERO_Click()
CurrentY=CY : CXX=4500
For P=1 To P9
For I=1 To NMM(P)
CurrentX=525+CXX : Print " M5=";
CX=2100+CXX
T1=Format(MMAXX(P,I),"0.00") & _
" kNm"
TW=TextWidth(T1)
CurrentX=CX-TW : Print T1 & _
" X= " & Format(LM(P,I),"0.00") _
& " m" & " P= " & P
Next I : Print
Next P
CY=CurrentY
End Sub
```

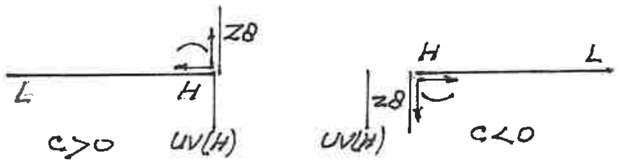
About STZ8.

Calculation of the largest maximum displacement Z8MAXX.
To calculate the maximum displacement ZMAX of a beam P subroutine ZMAXZ8, page 18, is called, and calls itself for each x subroutine H8Z8XX.

```
Private Sub H8Z8XX()          (see page 15 )
'Calculation of slope deflection H8
'and displacement Z8 at X meter
'from the left.
L1=L11(P) and after that follows

H8=0 : Z8=STZ8
.......
```

The displacements of the beam ends L and H of a beam P are UV(L) and UV(H) with the assumed direction downward.
STZ8 as start value for Z8 for H8Z8XX depends on the place of the beam axis system, BA(P)=L or BA(P)=H, and on the place of the beam end numbers L and H, the coordinates of L and H. The direction of the assumed displacement Z8 is that according to the perpendicular axis of the beam axis system. See the figures here below.



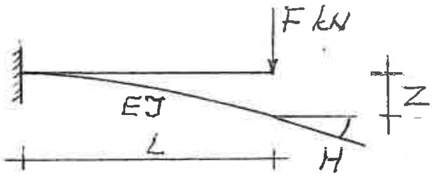


Calculation of the displacements Z8 for the elastic curve starts at the member end where the beam axis system is placed. At that beam end up to now angle H1 was determined and at the other beam end R2 and M2.
Beam ends which can displace will get a value after the main calculation. Then the value at the beam end where the beam axis system is placed must be determined, that is ST8Z, Z8=STZ8.
D1=X1(H)-X1(L), L1=Sqr(D1^2) and C=D1/L1.

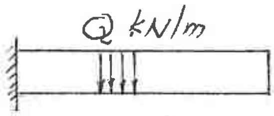
If BA(P)=L then the start value of Z8 is
STZ8=UV(L)*C,
if X1(H)>X1(L) then D1>0, so C=D1/L1= 1>0,
STZ8=UV(L)*1= UV(L) and
if X1(H)<X1(L) then D1<0, so C=D1/L1=-1<0,
STZ8=UV(L)*(-1)=-UV(L), both correct.

If BA(P)=H then is STZ8=-UV(H)*C,

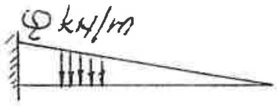
if X1(H)>X1(L) then D1>0, then C=1>0, and
STZ8=-UV(H)*1=-UV(H), and
if X1(H)<X1(L) then D1<0, then C=-1<0, and
STZ9=-UV(H)*(-1)= UV(H), again both correct like the second two pictures show.



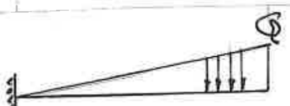
H= F*L^2/(2*EI)   Z= F*L^3/(3*EI)



H= Q*L^3/(6*EI)   Z= Q*L^4/(8*EI)

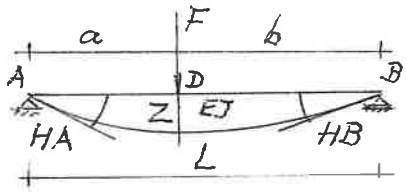


H= Q*L^3/(24*EI)   Z= Q*L^4/(30*EI)



H= Q*L^3/(8EI)   Z= 11Q*L^3/(120EI)

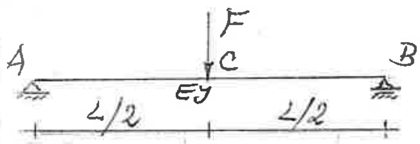
H= M*L/EI   Z= M*L^2/(2*EI)



HA= F*a*b*(L+b)/(6*L*EI)

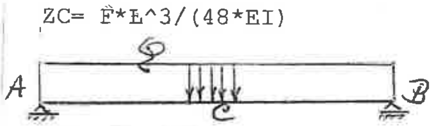
HB= F*a*b*(L+a)/(6*L*EI)

ZD= F*a^2*b^2/(3*L*EI)



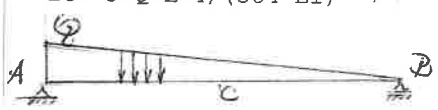
HA= HB= F*L^2/(16*EI)

ZC= F*L^3/(48*EI)



HA= HB= Q*L^3/(24*EI)

ZC= 5*Q*L^4/(384*EI)



HA= Q*L^3/(45*EI)

HB= 7*Q*L^3/(360*EI)

ZC= (5*Q*L^4/(384*EI))/2

Standard formulas for simple beams.

E is modulus of elasticity in kN/m^2
EI is bending stiffness, EI is E*I with
I is moment of inertia in m^4

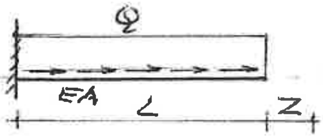
EI is (kN/m^2)*m^4 is kNm^2

EA is strain stiffness, EA is E*A with
A is cross sectial area in m^2

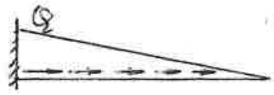
EA is (kN/m^2)*m^2 is kN

Displcement Z in m, angle H in radians

Z=F*L/EA

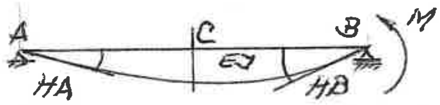


Z=Q*L^2/(2*EA)



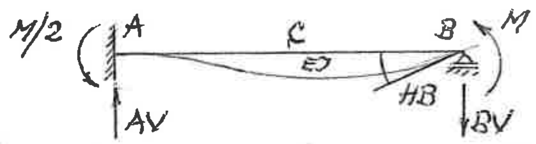
Z=Q*L^2/(6*EA)

Z=Q*L^2/(3EI)



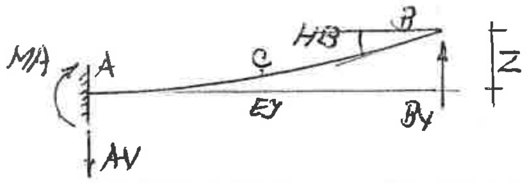
HA= M*L/(6*EI)   HB= M*L/(3*EI)

ZC= M*L^2/(16*EI)



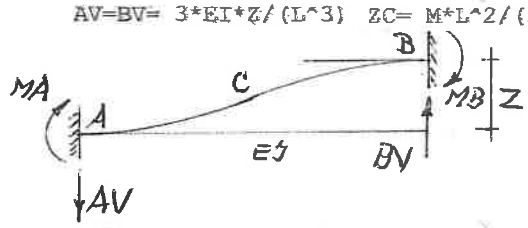
HB= M*L/(4*EI)   ZC= M*L^2/(32*EI)

AV=BV= 3*M/(2*EI)



MA=3*EI*Z/(L^2)   HB= 3*Z/(2*L)

AV=BV= 3*EI*Z/(L^3)   ZC= M*L^2/(32*EI)



MA=MB= 6*EI*Z/(L^2)   ZC= Z/2

AV=BV= 12*EI*Z/(L^3)

```
Private Sub CBEAMMAINCALC()

'1. Composition of construction
'matrix CC with member
'matrices S5.
CONSTRMATCCCBEAM
'2. Elements of force vector FF.
'2a. Joint load forces FY(I) and
'joint load moments MZ(I).
N=2*N9
For I=1 To N9
A=2*I-1 : B=2*I
FF(A)=FY(I) : FF(B)=MZ(I)
PP(A)=PV(I) : PP(B)=PR(I)
UU(A)=UV(I) : UU(B)=UR(I)
SS(A)=SV(I) : SS(B)=SR(I)
Next I

'2b. Primary forces and moments
'due to member loads perpendicular
'to the member axis.
For P=1 To P9 : L=LL(P) : H=HH(P)
EI=EII(P)
D1=X1(H)-X1(L)
L1=Sqr(D1^2)
If LE(P)=1 And RE(P)=1 Then
M1=0 : M2=0
BEAM1
ElseIf LE(P)=1 Or RE(P)=1 Then
M1=0 : M2=0 : M3=0 : M4=0
BEAM2
ElseIf LE(P)=0 And RE(P)=0 Then
BEAM3
End If
'primary moments and forces
M11(P)=M1 : R11(P)=R1
M22(P)=M2 : R22(P)=R2

C=D1/L1
If BA(P)=L Then
D4(P,1)=R1*C : D4(P,2)=R2*C
MP(P,1)=M1 : MP(P,2)=-M2
HE(P,1)=H1 : HE(P,2)=H2
Else If BA(P)=H Then
D4(P,1)=-R2*C : D4(P,2)=-R1*C
MP(P,1)=-M2 : MP(P,2)=M1
HE(P,1)=H2 : HE(P,2)=H1
End If
Next P

'2c Alteration of force vector FF.
For I=1 To N9
A=2*I-1 : B=2*I
For P=1 To P9 : L=LL(P) : H=HH(P)
I I<=L Then
FF(A)=FF(A)+D4(P,1)
FF(B)=FF(B)+MP(P,1)
Else If I=H Then
FF(A)=FF(A)+D4(P,2)
FF(B)=FF(B)+MP(P,2)
End If
Next P
Next I

'3 Alteration of force vector FF
'and concstruction matrix CC.
'3a Of FF in case of prescribed
'displacements <>0.
For I=1 To N
If UU(I)<>0 Then
For K=1 To N
FF(K)=FF(K)-CC(K,I)*UU(I)
Next K
End If
Next I

'3b. Of FF and CC in case of pres-
'cribed displacements.
For I=1 To N
If PP(I)=1 Then
For J=1 To N
CC(I,J)=0 : CC(J,I)=0
Next J
CC(I,I)=1 : FF(I)=UU(I)
End If
Next I

'3c. Of FF and CC if the joint is
'a hinge.
For I=1 To N
If CC(I,I)=0 Then CC(I,I)=1 _
                          FF(I)=0
Next I

'3d. Of CC in case of springy/
'elastic supports.
For I=1 To N
If SS(I)>0 Then
CC(I,I)=CC(I,I)+SS(I)
End If
Next I

'4. Calculation of the unknown
'displcements UV(I) and UR(I).
For I=1 To N : BB(I)=FF(I)
For J=1 To N
AA(I,J)=CC(I,J)
Next J
Next I          A x = b  is  C u = f

'The solution of N=2*N9
'equations.
GAUSS
For I=1 To N9
A=2*I-1 : B=2*I
UV(I)=XX(A) : UR(I)=XX(B)
UU(A)=XX(A) : UU(B)=XX(B)
Next I

'4b. Slope deflections separatedly
'calculated in case of hingy mem-
'ber ends.
For P=1 To P9 : L=LL(P) : H=HH(P)
D1=X1(H)-X1(L)
L1=Sqr(D1^2)

ZL=UV(L) : ZH=UV(H) H6=(ZH-ZL)/L1
H7=1.5*(ZH-ZL)/L1

If NL(P)=1 And NH(P)=1 Then

If D1>0 Then _
HE(P,1)=HE(P,1)+H6 : _
HE(P,2)=HE(P,2)+H6

If D1<0 Then _
HE(P,1)=HE(P,1)-H6 : _
HE(P,2)=HE(P,2)-H6
```

```
ElseIf NL(P)=1 Then
If D1>0 Then _
HE(P,1)=HE(P,1)+H7-0.5*UR(H)
If D1<0 Then _
HE(P,1)=HE(P,1)-H7-0.5*UR(H)

ElseIf NH(P)=1 Then _
If D1>0 Then _
HE(P,2)=HE(P,2)+H7-0.5*UR(L)
If D1<0 Then _
HE(P,2)=HE(P,2)-H7-0.5*UR(L)
End If
Next P

'5. Calculation of the member end
'forces w.r.t. the construction
'axes system X-Y.
'5a. Deuto the displacements
'alone.
For P=1 To P9 : L=LL(P) : H=HH(P)
EI=EII(P)
MEMBERMATS5CBEAM
TT(1)=2*L-1 : TT(2)=2*L
TT(3)=2*H-1 : TT(4)=2*H
For I=1 To 4 : FK(P,I)=0
For J=1 To 4 : A=TT(J)
FK(P,I)=FK(P,I)+S5(I,J)*UU(A)
Next J
Next I

'5b. Due to displacements and
'member/beam loads perpendicular
'to the member/beam axis..
D6(P,1)=FK(P,1)-D4(P,1)
MF(P,1)=FK(P,2)-MP(P,1)
D6(P,2)=FK(P,3)-D4(P,2)
MF(P,2)=FK(P,4)-MP(P,2)
Next P

'6. Calculation of the joint 'for-
'ces' KV(I) and KM(I).
'6a. Due to the displacements
'alone.
CONSTRMATCCCBEAM
For I=1 To N9
A=2*I-1 : B=2*I
KV(I)=0 : KM(I)=0
For J=1 To N
KV(I)=KV(I)+CC(A,J)*UU(J)
KM(I)=KM(I)+CC(B,J)*UU(J)
Next J

'6b. Due to displacements and
'member loads perpendicular to the
'member axis.
For P=1 To P9 : L=LL(P) : H=HH(P)
If I=L Then
KV(I)=KV(I)-D4(P,1)
KM(I)=KM(I)-MP(P,1)
Else If I=H Then
KV(I)=KV(I)-D4(P,2)
KM(I)=KM(I)-MP(P,2)
End If
Next P
Next I
```

```
Private Sub MEMBERMATS5CBEAM()

D1=X1(H)-X1(L)
L1=Sqr(D1^2).
If NL(P)=0 And NH(P)=0 Then
A=12*EI/L1^3 : B=6*EI/L1^2
D=4*EI/L1 : E=2*EI/L1
If D1<0 Then B=-B
FILLINGS5CBEAM

ElseIf NL(P)=1 And NH(P)=1 Then
A=0 : B=0 : D=0 : E=0
FILLINGS5CBEAM

Else If NL(P)=1 Or NH(P)=1 Then
A=3*EI/L1^3 : B=3*EI/L1^2
D=3*EI/L1

If NL(P)=1 Then
If D1<0 Then B=-B
FILLINGS5CBEAM
For I=1 To 4
S5(2,I)=0 : S5(I,2)=0
Next I

ElseIf NH(P)=1 Then
If D1<0 Then B=-B
FILLINGS5CBEAM
For I=1 To 4
S5(4,I)=0 : S5(I,4)=0
Next I
End If
End If

End Sub

Private Sub FILLINGS5CBEAM

'Row 1 Of S5.
S5(1,1)=A : S5(1,2)=B : S5(1,3)=-A
S5(1,4)=B
'Row 2.
S5(2,1)=B : S5(2,2)=D : S5(2,3)=-B
S5(2,4)=E
'Row 3.
S5(3,1)=-A : S5(3,2)=-B
S5(3,3)=A : S5(3,4)=-B
'Row 4.
S5(4,1)=B : S5(4,2)=E : S5(4,3)=-B
S5(4,4)=D

End Sub
```

```
'7. Calculation of the reactions.
For I=1 To N9
If SV(I)>0 Then
RV(I)=SV(I)*UV(I)
Else
RV(I)=-KV(I)+FY(I)
End If
If SR(I)>0 Then
RM(I)=SR(I)*UR(I)
Else
RM(I)=-KM(I)+MZ(I)
End If
Next I

End Sub
```

```
Private Sub CONSTRMATCCCBEAM
N=2*N9
For I=1 To N : For J=1 To N
CC(I,J)=0 : Next J : Next I
For P=1 To P9 : L=LL(P) : H=HH(P)
EI=EII(P)
MEMBERMATS5CBEAM
TT(1)=2*L-1 : TT(2)=2*L
TT(3)=2*H-1 : TT(4)=2*H
For I=1 To 4 : I1=TT(I)
For J=1 To 4 : J1=TT(J)
CC(I1,J1)=CC(I1,J1)+S5(I,J)
Next J
Next I
Next P
End Sub
```

```
Private Sub BEAM1()
'The statically determinate beam on
'two supports, the simple beam.
'Calculation of the support reac-
'tions and the slopes at the beam
'ends.
R1=0 : R2=0 : H1=0 : H2=0
'The concentrated loads.
For I= 1 To NFB(P)
F2=F22(P,I) : L2=L22(P,I)
R4=F2*L2/L1 : R3=F2-R4
R1=R1+R3 : R2=R2+R4
H5=F2*L2^2/(2*EI)
Z1=F2*L2^3/(3*EI)+H5*(L1-L2)
Z2=R4*L1^3/(3*EI)
H3=(Z2-Z1)/L1 : H8=R4*L1^2/(2*EI)
H4=H3+H5-H8
H1=H1+H3 : H2=H2+H4
Next I
'The distributed loads.
For I=1 to NQT(P)
Q3=Q33(P,I) : Q4=Q44(P,I)
L3=L33(P,I) : L4=L44(P,I)
L5=L1-L3-L4
QLOAD
R4=T*(L3+A1)/L1 : R3=T-R4
R1=R1+R3 : R2=R2+R4
Z2=R4*L1^3/(3*EI)
H3=(Z2-Z1)/L1 : H8=R4*L1^2/(2*EI)
H4=H3+H7-H8
H1=H1+H3 : H2=H2+H4
Next I
'The beam end moments M1 and M2.
R4=(M2-M1)/L1 : R3=-R4
R1=R1+R3 : R2=R2+R4
H3=-M1*L1/(3*EI)-M2*L1/(6*EI)
H4=M1*L1/(6*EI)+M2*L1/(3*EI)
H1=H1+H3 : H2=H2+H4
End Sub
```

```
Private Sub QLOAD()
'The statically determinate on the
'left clamped beam with trapeze
'like distributed load.

T=0.5*(Q3+Q4)*L4
B1=(2*Q3+Q4)*L4/(3*(Q3+Q4))
A1=L4-B1 : M=T*A1
```

```
Private Sub BEAM2()
'The onefold statically indetermi-
'nate beam on two supports.
'Calculation of the reactions and
'the slope at the not clamped beam-
'end.
R1=0 : R2=0
H1=0 : H2=0
For I=1 To NFB(P)
F2=F22(P,I) : L2=L22(P,I)
If LE(P)=1 Then L2=L1-L2
H5=F2*L2^2/(2*EI)
Z1=F2*L2^3/(3*EI)+H5*(L1-L2)
R4=Z1*(3*EI)/(L1^3)
M3=F2*L2-R4*L1 : R3=F2-R4
R1=R1+R3 : R2=R2+R4 : M1=M1+M3
H8=R4*L1^2/(2*EI)
H4=H5-H8 : H2=H2+H4
Next I
'The distributed loads.
For I=1 To NQB(P)
Q3=Q33(P,I) : L3=L33(P,I)
Q4=Q44(P,I) : L4=L44(P,I)
L5=L1-L3-L4

If LE(P)=1 Then
Q3=Q4 : Q4=Q33(P,I) : L3=L1-L3-L4
L5=L1-L3-L4
End If

QLOAD
R4=Z1*(3*EI)/L1^3
M3=T*(L3+A1)-R4*L1 : R3=T-R4
R1=R1+R3 : R2=R2+R4 : M1=M1+M3
H8=R4*L1^2/(2*EI)
H4=H7-H8 : H2=H2+H4
Next I

If LE(P)=1 Then
R=R1 : R1=R2 : R2=R : M2=M1 : M1=0
H1=-H2 : H2=0
End If
If LE(P)=0 Then
R3=-1.5*M4/L1 : R4=1.5*M4/L1
M3=-M4/2 : H4=M4*L1/(4*EI)
R1=R1+R3 : R2=R2+R4 : M1=M1+M3
M2=M4 : H2=H2+H4

ElseIf LE(P)=1 Then

R3=1.5*M4/L1 : R4=-1.5*M4/L1
M3=-M4/2 : H4=M4*L1/(4*EI)
R1=R1+R3 : R2=R2+R4 : M2=M2+M3
M1=M4 : H1=H1-H4
End If

End Sub
```

```
Z5=T*L3^3/(3*EI)+M*L3^2/(2*EI)
H5=T*L3^2/(2*EI)+M*L3/EI
Z6=Q4*L4^4/(8*EI)
Z6=Z6-(Q4-Q3)*L4^4/(30*EI)
H6=Q4*L4^3/(6*EI)
H6=H6-(Q4-Q3)*L4^3/(24*EI)

H7=H5+H6 : Z7=Z5+H5*L4+Z6
Z1=Z7+H7*L5
End Sub
```

```
Private Sub BEAM3()
'The twofold statically indtermi-
'nate beam on two supports
'Calculation of the reactions.
R1=0 : R2=0 : M1=0 : M2=0
H1=0 : H2=0
'The concentrated loads.
For I=1 To NFB(P)
F2=F22(P,I) : L2=L22(P,I)
H5=F2*L2^2/(2*EI)
Z1=F2*L2^3/(3*EI)+H5*(L1-L2)
A=L1^3/(3*EI) : B=-L1^2/(2*EI)
C=Z1
D=L1^2/(2*EI) : E=-L1/EI : F=H5
TWOEQUATIONS
M3=F2*L2-R4*L1+M4 : R3=F2-R4
R1=R1+R3 : R2=R2+R4
M1=M1+M3 : M2=M2+M4
Next I
'The distributed loads.
For I=1 To NQB(P)
Q3=Q33(P,I) : L3=L33(P,I)
Q4=Q44(P,I) : L4=L44(P,I)
L5=L1-L3-L4
QLOAD
A=L1^3/(3*EI) : B=-L1^2/(2*EI)
C=Z1
D=L1^2/(2*EI) : E=-L1/EI : F=H7
TWOEQUATIONS
M3=T*(L3+A1)-R4*L1+M4 : R3=T-R4
R1=R1+R3 : R2=R2+R4
M1=M1+M3 : M2=M2+M4
Next I
End Sub
```

```
Private Sub TWOEQUATIONS()
R4=(C-B*(C*D-A*F)/(D*B-A*E))/A
M4=(C*D-A*F)/(D*B-A*E)
End Sub
```

```
Private Sub T5M5XX()
'Calculation of transverse force T5
'and T7, and bending moment M5 at
'X meter from the 'left'
L1=L11(P)
T5=0 : T7=0 : M5=0

'The concentrated loads.
For I=1 TO NFB(P)
F2=F22(P,I) : L2=L22(P,I)
R3=F2*(L1-L2)/L1
If X<=L2 Then
T6=R3 : M6=R3*X
ElseIf X>L2 Then
T6=R3-F2 : M6=R3*X-F2*(X-L2)
End If
T5=T5+T6 : T7=T7+T6 : M5=M5+M6
If X=L2 Then
T7=T5-F2
End If
Next I
```

```
Private Sub T5M5X()
'Calculation of transverse force
'T5 and T7, and bending moment M5
'at X meter from the 'left'.
L1=L11(P)
T5=R1 : T7=R1 : M5=-M1
M5=M5+R1*X
'The concentrated loads.
For I=1 To NFB(P)
F2=F22(P,I) : L2=L22(P,I)
If X>L2 Then
T5=T5-F2 : T7=T7-F2
M5=M5-F2*(X-L2)
ElseIf X=L2 Then
T7=T7-F2
ElseIf X<L2 Then
Exit For
End If
Next I
'The distributed loads.
For I=1 To NQB(P)
Q3=Q33(P,I) : L3=L33(P,I)
Q4=Q44(P,I) : L4=L44(P,I)
If X>L3 Then
If X>L3 And X<=L3+L4 Then
Q5=Q3+(Q4-Q3)*(X-L3)/L4
T=0.5*(Q3+Q5)*(X-L3)
B1=(2*Q3+Q5)*(X-L3)/(3*(Q3+Q5))
T5=T5-T : T7=T7-T
M5=M5-T*B1
ElseIf X>L3+L4 Then
T=0.5*(Q3+Q4)*L4
B1=(2*Q3+Q4)*L4/(3*(Q3+Q4))
T5=T5-T : T7=T7-T
M5=M5-T*(B1+(X-L3-L4))
End If
End If
Next I

End Sub
```

```
'The distributed loads.
For I=1 To NQB(P)
Q3=Q33(P,I) : L3=L33(P,I)
Q4=Q44(P,I) : L4=L44(P,I)
QLOAD
R3=T*(B1+(L1-L3-L4))/L1
If X<=L3 Then
T6=R3 : M6=R3*X
Else If X>L3 And X<=L3+L4 Then
Q5=Q3+(Q4-Q3)*(X-L3)/L4
Q4=Q5 : L4=X-L3
QLOAD
T6=R3-T : M6=R3*X-T*B1
Else If X>L3+L4 Then
QLOAD
T6=R3-T : M6=R3*X-T*(X-L3-L4+B1)
End If
T5=T5+T6 : T7=T7+T6 : M5=M5+M6
Next I

'The member end moments M1 and M2.
R3=(M1-M2)/L1
T6=R3 : M6=R3*X-M1
T5=T5+T6 : T7=T7+T6 : M5=M5+M6

End Sub
```

```
Private Sub H8Z8XX()
'Calculation of slope deflection H8
'and displacement Z8 at X meter
'from the left.

L1=L11(P)
H8=0 : Z8=0

'Due to angle H1.
H9=H1 : Z9=H1*X

'Due to the reaction R2.
M=R2*(L1-X)
H4=R2*X^2/(2*EI)+M*X/EI
Z4=R2*X^3/(3*EI)+M*X^2/(2*EI)
H8=H8+H9-H4 : Z8=Z8+Z9-Z4

'The concentrated loads..
For I=1 To NFB(P)
F2=F22(P,I) : L2=L22(P,I)
If X<=L2 Then
M=F2*(L2-X)
H9=F2*X^2/(2*EI)+M*X/EI
Z9=F2*X^3/(3*EI)+M*X^2/(2*EI)
ElseIf X>L2 Then
H9=F2*L2^2/(2*EI)
Z9=F2*L2^3/(3*EI)+H9*(X-L2)
End If
H8=H8+H9 : Z8=Z8+Z9
Next I

'The distributed loads.
For I=1 To NQB(P)
Q3=Q33(P,I) : L3=L33(P,I)
Q4=Q44(P,I) : L4=L44(P,I)
If X<=L3 Then
QLOAD             page
M=T*(L3-X+A1)
H9=T*X^2/(2*EI)+M*X/EI
Z9=T*X^3/(3*EI)+M*X^2/(2*EI)
ElseIf X>L3 And X<L3+L4 Then
Q5=Q3+(Q4-Q3)*(X-L3)/L4
Q4=Q5 : L4=X-L3
QLOAD
H9=H7 : Z9=Z7
Q4=Q44(P,I) : L4=L44(P,I)
Q3=Q5 : L4=L3+L4-X
QLOAD
M=T*A1
H4=T*X^2/(2*EI)+M*X/EI
Z4=T*X^3/(3*EI)+M*X^2/(2*EI)
H9=H9+H4 : Z9=Z9+Z4
ElseIf X>=L3+L4 Then
L5=X-L3-L4
QLOAD
H9=H7 : Z9=Z1
End If
H8=H8+H9 : Z8=Z8+Z9
Next I
'The member end moment M2.
H9=M2*X/EI : Z9=M2*X^2/(2*EI)
H8=H8+H9 : Z8=Z8+Z9
'Member end displacements.
H9=(REZ-LEZ)/L1
Z9=LEZ+(REZ-LEZ)*X/L1
H8=H8+H9 : Z8=Z8+Z9
End Sub
```

```
Private Sub T5M5G()
NB=0 : L1=L11(P)
For XG=0 To L1+G Step G
If XG=0 Then
X=XG : T5M5XX
T5M5

ElseIf XG>0 And XG<L1 Then
For I1=1 To NFB(P): L2=L22(P,I1)
If L2>XG-G And L2<XG Then
X=L2 : T5M5XX
T5M5
End If
Next I1
X=XG : T5M5XX
T5M5

ElseIf XG>=L1 And XG<L1+G Then
For I1=1 To NFB(P): L2=L22(P,I1)
If L2>XG-G Then
X=L2 : T5M5XX
T5M5
End If
Next I1
X=L1 : T5M5XX
T5M5
End If
Next XG : NBC(P)=NB
End Sub

Private Sub T5M5()
NB=NB+1 : LB(P,NB)=X
NBL(P,NB)=T5 : NBR(P,NB)=T7
NBM(P,NB)=M5
End Sub
```

```
Private Sub H8Z8G()
NC=0 : L1=L11(P)
For XG=0 To L1+G Step G
If XG=0 Then
X=XG : H8Z8XX
H8Z8
ElseIf XG>0 And XG<L1 Then
For I1=1 To NFB(P): L2=L22(P,I1)
If L2>XG-G And L2<XG Then
X=L2 : H8Z8XX
H8Z8
End If
Next I1 : X=XG : H8Z8XX
H8Z8

ElseIf XG>=L1 And XG<L1+G Then
For I1=1 To NFB(P): L2=L22(P,I1)
If L2>XG-G Then
X=L2 : H8Z8XX
H8Z8
End If
Next I1 : X=L1 : H8Z8XX
H8Z8
End If
Next XG : NCC(P)=NC
End Sub

Private Sub H8Z8()
NC=NC+1 : LC(P,NC)=X
NH8(P,NC)=H8 : NZ8(P,NC)=Z8
End Sub
```

```
Private Sub MMAXM5()
'Calculation of the largest ben-
'ding moment and the moment zero
'points.
NM=0 : L1=L11(P)
For X=0 To L1+0.01 Step 0.01
T5M5XX

If X=0 Then
M7=M5 : T3=T5
NM=NM+1
MMAXX(P,NM)=M5 : LM(P,NM)=X

ElseIf X>0 And X<L1 Then

If M5>=0 And M7<0 Or _
              M5<=0 And M7>0 Then
NM=NM+1
MMAXX(P,NM)=M5 : LM(P,NM)=X
End If
M7=M5

If T5<=0 And T3>0 Or _
             T5>=0 And T3<0 Then
NM=NM+1
MMAXX(P,NM)=M5 : LM(P,NM)=X
End If
T3=T5

ElseIf X>=L1 Then
X=L1 : T5M5XX
NM=NM+1
MMAXX(P,NM)=M5 : LM(P,NM)=X
End If

Next X

End Sub
```

```
Private Sub ZMAXZ8()
'Calculation of the largest dis-
'placement/bending and the ben-
'ding zero points.
NZ=0 : L1=L11(P) : EI=EII(P)
For X=0 To L1+0.01 Step 0.01
H8Z8XX        page 15

If X=0 Then
Z3=Z8 : H3=H8 : NZ=NZ+1
ZMAXX(P,NZ)=Z8 : LZ(P,NZ)=X

ElseIf X>0 And X<L1 Then

If Z8<=0 And Z3>0 Or _
   Z8>=0 And Z3<0 Then
NZ=NZ+1
ZMAXX(P,NZ)=Z8 : LZ(P,NZ)=X
End If
Z3=Z8

If H8<=0 And H3>0 Or _
   H8>=0 And H3<0 Then
NZ=NZ+1
ZMAXX(P,NZ)=Z8 : LZ(P,NZ)=X
End If
H3=H8
```

```
ElseIf X>=L1 Then
X=L1 : H8Z8XX
NZ=NZ+1
ZMAXX(P,NZ)=Z8 : LZ(P,NZ)=X
Exit For
End If

Next X

ZMAX=0
For I=1 To NZ
If Abs(ZMAXX(P,I))>Abs(ZMAX) Then
ZMAX=ZMAXX(P,NZ) : X=LZ(P,I)
End If
Next I
NZ=NZ+1
ZMAXX(P,NZ)=ZMAX : LZ(P,NZ)=X
NZZ(P)=NZ

End Sub
```

```
Private Sub LINEXAYAXBYB()
If PRP=0 Then
Line (XA,YA)-(XB,YB)
ElseIf PRP=1 Then
Printer.Line (XA,YA)-(XB,YB)
End If
End Sub
```