A.6.4. COP 2002– Connections Calculation Sheets*

Electronic Appendix included in the annexed CD-Rom

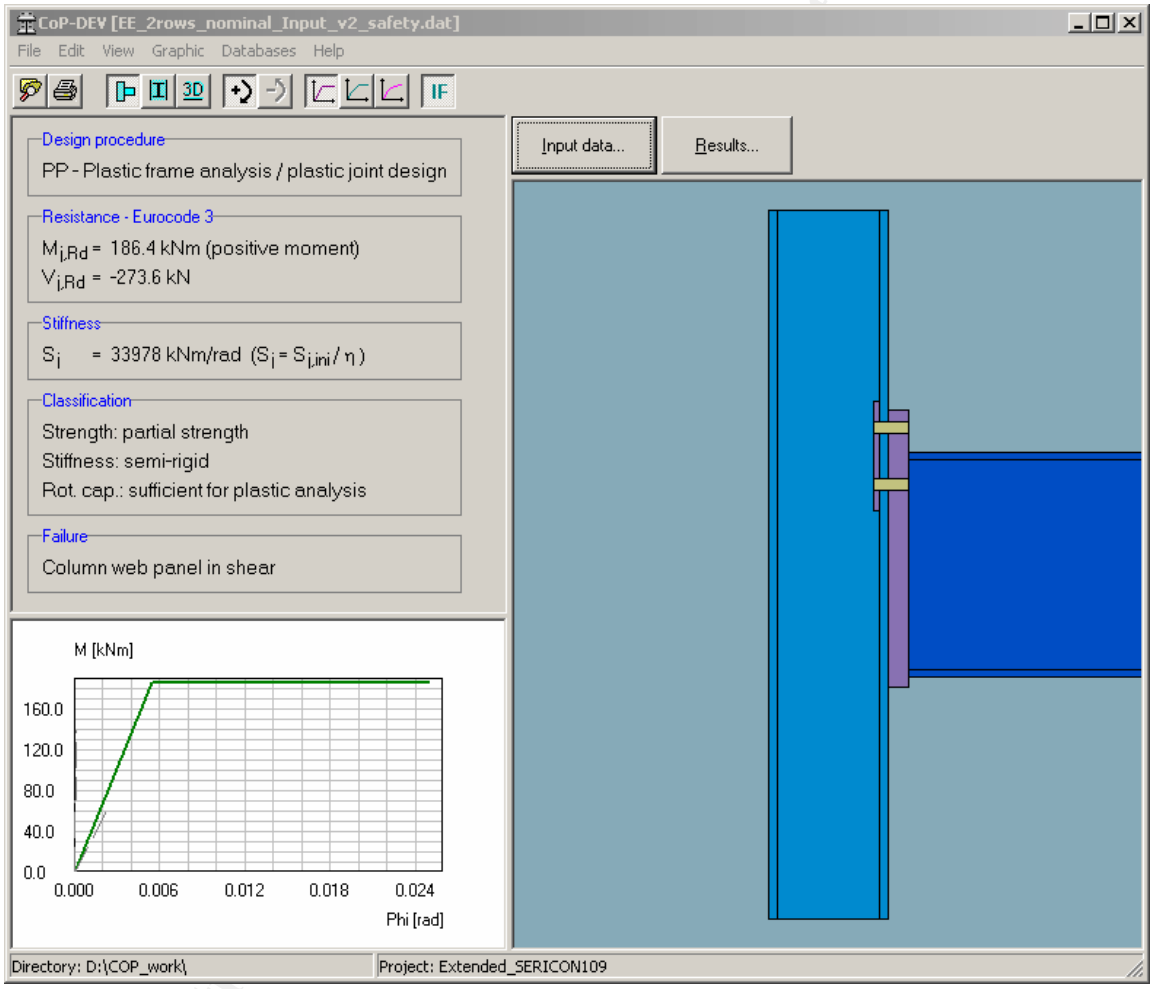
* The Connection Program - **COP 2002** – MSM, RWTH, ICCSbv – Hoofddorp, The Netherlands

Index

SERICON 109005 Extended Endplate Joint

SERICON 109005, nominal properties, safety factors

Design of joints in building frames
according to Eurocode 3 - revised Annex J



1. INPUT DATA

1.1 PROJECT DATA

```
project .....................: MSC in Civil Engineering - Structures
structure ...................: SERICON 109005 Nominal+ safety factors
joint .......................: Extended End-plate
```

```
joint id ....................: 109005
engineer ....................: LB
date ........................: 28-03-2003

design procedure ............: plastic analysis / plastic joint design

environment .................: not corrosive
framing .....................: not braced
```

1.2 main joint data

```
beam :                    IPE 450,  S 235
column :                  HEB 240,  S 235
extended end plate :      553 X 239 X 41,  S 235

backing plates
```

1.3 mechanical characteristics

	yield strength N/mm²	ultimate strength N/mm²
beam web	235.00	360.00
beam flange	235.00	360.00
column web	235.00	360.00
column flange	235.00	360.00
end plate	235.00	360.00
bolts in tension	900.00	1000.00
backing plates	235.00	

1.4 geometrical characteristics

1.4.1 beam : IPE 450, S 235

```
depth ..................................................:      454.00 mm
width ..................................................:      192.00 mm
thickness of the flange ................................:       14.00 mm
thickness of the web ...................................:       10.40 mm
root radius ............................................:       21.00 mm
inertia ................................................:    34371.97 cm4
area ...................................................:      101.85 cm²
length of the beam connected to the column .............:      693.00 mm
beam inclination .......................................:        0.00 °
```

1.4.2 column : HEB 240, S 235

```
depth ..................................................:      242.00 mm
width ..................................................:      240.00 mm
thickness of the flange ................................:       16.40 mm
thickness of the web ...................................:       10.40 mm
root radius ............................................:       21.00 mm
inertia ................................................:    11205.79 cm4
area ...................................................:      104.26 cm²
```

1.4.3 end plate 553 X 239 X 41, S 235

```
vertical distance between the beam flange and the edge
   of the end plate ....................................:      84.00 mm
vertical distance between the first bolt row and the
   edge of the end plate ...............................:      35.00 mm
vertical distance between the bolt rows 1 and 2 .......:     115.00 mm
horizontal distance between the bolts .................:     109.00 mm
horizontal distance between the bolts and the edge
   of the end plate ....................................:      65.00 mm
```

1.4.4 backing plates

```
thickness of the plate ................................:      12.00 mm
width of the plate ....................................:      92.00 mm
length of the plate ...................................:     219.00 mm
yield strength ........................................:     235.00 N/mm²
```

1.4.5 bolts in tension 10.9

```
resistant area ........................................:     353.00 mm²
diameter of the shank .................................:      24.00 mm
diameter of the holes .................................:      26.00 mm
thickness of the bolt head ............................:      15.00 mm
thickness of the nut ..................................:      19.00 mm
total thickness of the washer(s) per bolt .............:       4.00 mm
diameter of the washers ...............................:      44.00 mm
```

1.4.6 welds

```
thickness of the weld connecting the beam flange ......:       9.02 mm
thickness of the weld connecting the beam web .........:       5.00 mm
```

1.5 safety factors

```
gamma M0 ..............................................:       1.10
gamma M1 ..............................................:       1.10
gamma Mb ..............................................:       1.25
gamma Mw ..............................................:       1.25
```

2. JOINT PROPERTIES FOR POSITIVE MOMENTS

2.1 CALCULATION OF THE COMPONENTS

2.1.1 column web panel in shear

```
sheared area of the column ..........................: Avc    =      34.14 cm²
beta coefficient ..................... ( J.2.6.3 ) : BETA   =       1.00
plastic resistance of the column web panel .........: VwpRd  =     378.94 kN
   ( J.3.5.1)
resistance : vwprd / beta ...........................: FwpRd  =     378.94 kN

stiffness coefficient ............. ( Form. J.39 ) : k1     =       2.91 mm
```

2.1.2 column web in compression

```
effective width ..................... ( Form. J.20 ) : l1     =      308.51 mm
                                                        l2     =      269.76 mm
                                                   => beff   =      269.76 mm

coefficient for stress interaction .. ( Table J.5 ) : RHO    =        0.73
longitudinal compressive stress in the web adjacent
   to the root radius ..............................: Sigma  =        0.00 N/mm²
reduction factor .................... ( Form. J.22 ) : kwc    =        1.00

strength : ( Form. J.17 )
   * buckling of the web :
     slenderness .....................................: LAMBDA =        0.64
     strength ........................................: Fc2    =      437.35 kN

strength .............................................: FcwcRd =      437.35 kN

stiffness coefficient ............... ( Form. J.40 ) : k2     =       11.75 mm
```

2.1.3 column flange in bending

```
geometrical parameters .............. ( Fig. J.25 ) : e      =       65.50 mm
======================                               emin   =       65.00 mm
                                                     m      =       32.50 mm
                                                     n      =       40.62 mm
                                                     ew     =       11.00 mm
```

2.1.3.1 effective length of the equivalent t-stub (Tables J.6 - J.7)

```
1) bolts considered individually

   * circular patterns :
        2 Pi m .....................................: l      =      204.20 mm
   * other patterns :
        4 m + 1.25 e ...............................: l      =      211.87 mm

   for all bolt rows :
   * circular patterns .............................: leff   =      204.20 mm
   * other patterns ................................: leff   =      211.87 mm

2) bolts considered as part of a group

        group between bolt row nb
                                  circular patterns          other patterns
                                        (mm)                     (mm)

         1  -  2                        434.20                   326.8
```

2.1.3.2 strength

```
( J.3.5.4.2 )
design resistance of a bolt ....... ( Table 6.5.3 ) : BtRd   =      254.16 kN

1) bolts considered individually
   ----------------------------
```

```
*  bolt row nb 1

   longitudinal compressive stress in the flange ...: Sigma  =        0.00 N/mm²
   reduction factor ................ ( Form. J.29 ) : kfc    =        1.00

   mode of collapse for equivalent T-stub ( J.3.2.1 )

   design plastic resistance of the T-stub ( Form. J.7 )
      for complete yielding of the flange ..........: Mpl1Rd =     2933.37 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =     3043.57 Nm
   design moment resistance for the backing plates .: MbpRd  =     1570.51 Nm

   mode 1 : complete yielding of the flange ........: F1Rd   =      457.68 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      365.64 kN
   mode 3 : bolts failure ..........................: F3Rd   =      508.32 kN
            ( Form. J.9 - J.5 - J.6 )

   strength ........................................: FtRd(1)  =      365.64 kN

*  bolt row nb 2

   longitudinal compressive stress in the flange ...: Sigma  =        0.00 N/mm²
   reduction factor ................ ( Form. J.29 ) : kfc    =        1.00

   mode of collapse for equivalent T-stub ( J.3.2.1 )

   design plastic resistance of the T-stub ( Form. J.7 )
      for complete yielding of the flange ..........: Mpl1Rd =     2933.37 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =     3043.57 Nm
   design moment resistance for the backing plates .: MbpRd  =     1570.51 Nm

   mode 1 : complete yielding of the flange ........: F1Rd   =      457.68 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      365.64 kN
   mode 3 : bolts failure ..........................: F3Rd   =      508.32 kN
            ( Form. J.9 - J.5 - J.6 )

   strength ........................................: FtRd(2)  =      365.64 kN

2) bolts considered as part of a group
   ----------------------------------

*  group between bolt row nb 1 to nb 2

   longitudinal compressive stress in the flange ...: Sigma  =        0.00 N/mm²
   reduction factor ................ ( Form. J.29 ) : kfc    =        1.00

   mode of collapse for equivalent T-stub ( J.3.2.1 )

   design plastic resistance of the T-stub ( Form. J.7 )
      for complete yielding of the flange ..........: Mpl1Rd =     4695.53 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =     4695.53 Nm
   design moment resistance for the backing plates .: MbpRd  =     2513.97 Nm
            ( Form. J.10 )

   mode 1 : complete yielding of the flange ........: F1Rd   =      732.62 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      693.22 kN
   mode 3 : bolts failure ..........................: F3Rd   =     1016.64 kN
```

```
   strength ....................................: FtRd(1,2)=      693.22 kN
```

2.1.3.3 stiffness

```
   *  effective length of the equivalent t-stub
      bolt rows are considered individually or as part of a group

      bolt row nb  1 ..............................: beff(1)  =     163.44 mm
      bolt row nb  2 ..............................: beff(2)  =     163.44 mm

   *  stiffness coefficient ( Form. J.42 )

      bolt row nb  1 ..............................: k3(1)    =      17.85 mm
      bolt row nb  2 ..............................: k3(2)    =      17.85 mm
```

2.1.4 column web in tension

2.1.4.1 strength

bolt row nb	coefficient for stress interaction (Table J.5)	strength (kN)
1	0.81	379.13
2	0.81	379.13
group between bolt row nb		
1 - 2	0.66	480.00

2.1.4.2 stiffness

```
      bolt row nb  1 ..............................: k4(1)    =       7.12 mm
      bolt row nb  2 ..............................: k4(2)    =       7.12 mm
```

2.1.5 end plate in bending

```
   geometrical parameters ..... ( Fig. J.28 ) : e      =      65.50 mm
   ======================                       m      =      43.64 mm
                                                ex     =      35.00 mm
                                                mx     =      38.80 mm

      bolt row nb 2 ( below the top beam flange ) .....: m1     =      43.64 mm
                                                         m2     =      41.80 mm
         determination of the alpha coefficient .......: Lambda1=       0.40
            ( Fig. J.27 )                                Lambda2=       0.38
                                                         ALPHA  =       6.63

      bolt row nb 2 ( up to the bottom beam flange ) ..: m1     =      43.64 mm
                                                         m2     =     363.80 mm
         determination of the alpha coefficient .......: Lambda1=       0.40
            ( Fig. J.27 )                                Lambda2=       3.35
                                                         ALPHA  =       5.85
```

2.1.5.1 effective length of the equivalent t-stub (Tables J.8) :

```
      bolt row nb 1
```

```
   * circular patterns :
        2 Pi mx ..................................: l      =      243.76 mm
        Pi mx + w ................................: l      =      230.88 mm
        Pi mx + 2 e ..............................: l      =      251.88 mm
   * other patterns :
        4 mx + 1.25 ex ...........................: l      =      198.93 mm
        e + 2 mx + 0.625 ex ......................: l      =      164.47 mm
        0.5 w + 2 mx + 0.625 ex ..................: l      =      153.97 mm
        0.5 Bep ..................................: l      =      119.50 mm
   => effective length :
   * circular patterns ...........................: leff   =      230.88 mm
   * other patterns ..............................: leff   =      119.50 mm

   bolt row nb 2 ( influence of the upper beam flange )
   * circular patterns :
        2 Pi m1 ..................................: leff   =      274.22 mm
   * other patterns :
        Alpha m1 .................................: leff   =      289.29 mm

   bolt row nb 3 ( not influenced by the beam flanges )
   * circular patterns :
        2 Pi m1 ..................................: leff   =        0.00 mm
   * other patterns :
        4 m1 + 1.25 e ............................: leff   =        0.00 mm

   bolt row nb 2 ( influence of the lower beam flange )
   * circular patterns :
        2 Pi m1 ..................................: leff   =      274.22 mm
   * other patterns :
        Alpha m1 .................................: leff   =      289.29 mm
```

2.1.5.2 strength

```
*  bolt row nb 1

   mode of collapse for equivalent T-stub ( J.3.2.1 )

   design plastic resistance of the T-stub ( Form. J.7 )
      for complete yielding of the flange ..........: Mpl1Rd =    10728.79 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =    10728.79 Nm

   mode 1 : complete yielding of the flange ........: F1Rd   =     1106.20 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      531.86 kN
   mode 3 : bolts failure ..........................: F3Rd   =      508.32 kN
            ( Form. J.4 - J.5 - J.6 )

   strength ....................................: FtepRd(1)=      508.32 kN

*  bolt row nb 2

   mode of collapse for equivalent T-stub ( J.3.2.1 )

   design plastic resistance of the T-stub ( Form. J.7 )
      for complete yielding of the flange ..........: Mpl1Rd =    24619.48 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =    25973.09 Nm
```

```
   mode 1 : complete yielding of the flange ........: F1Rd   =     2256.43 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      811.40 kN
   mode 3 : bolts failure ..........................: F3Rd   =      508.32 kN

   strength ........................................: FtepRd(2)=     508.32 kN
```

2.1.5.3 stiffness

```
*  effective length of the equivalent t-stub
   bolt rows are considered individually or as part of a group

   bolt row nb  1 ..................................: leff(1) =      119.50 mm
   bolt row nb  2 ..................................: leff(2) =      137.11 mm

*  stiffness coefficient ( Form. J.43 )

   bolt row nb  1 ..................................: k5(1)  =      119.90 mm
   bolt row nb  2 ..................................: k5(2)  =       96.62 mm
```

2.1.5.4 bolts in tension

```
length of the bolt ................... ( J.4.4.10 ) : Lb     =       90.40 mm
strength ........................... ( Table 6.5.3 ) : BtRd   =      254.16 kN
stiffness coefficient ............... ( Form. J.45 ) : k7     =        6.25 mm
```

2.1.6 beam flange in compression

```
moment resistance of the beam cross-section .........: McRd   =      370.32 kNm
strength ............................ ( Form. J.30 ) : FcfbRd =      841.64 kN
```

2.1.7 beam web in tension

```
effective width
   => equal to the ones of the end plate in bending
```

2.1.7.1 strength

bolt row nb		strength (kN) (Form. J.31) FtwbRd(i)
2	:	642.76

2.2 ASSEMBLY OF THE COMPONENTS

2.2.1 strength (Fig. J.34)

2.2.1.1 bolt row nb 1

```
                                                              strength (kN)

column web panel in shear ..................................:      378.94
column web in compression ..................................:      437.35
column flange in bending ...................................:      365.64
```

```
   column web in tension ....................................:      379.13
   end plate in bending .....................................:      508.32
   bolts in tension .........................................:      508.32
   beam flange in compression ...............................:      841.64
                                                                  ---------
   resistance of bolt row nb  1 .....................: Frd(1) =      365.64 kN
```

2.2.1.2 bolt row nb 2

```
                                                                  strength (kN)
```

2.2.1.2.1 1) bolts considered individually

```
   column web panel in shear ................................:       13.30
   column web in compression ................................:       71.70
   column flange in bending .................................:      365.64
   column web in tension ....................................:      379.13
   end plate in bending .....................................:      508.32
   bolts in tension .........................................:      508.32
   beam flange in compression ...............................:      475.99
   beam web in tension ......................................:      642.76
```

2.2.1.2.2 2) bolts considered as part of a group

```
   group between bolt row nb 1 to nb 2

      column flange in bending ..............................:      327.58
      column web in tension .................................:      114.36

                                                                  ---------
   resistance of bolt row nb  2 .....................: Frd(2) =       13.30 kN


plastic distribution of the internal forces
```

2.2.1.3 summary

```
   resistance of bolt row nb  1 .....................: FRd(1) =      365.64 kN
   resistance of bolt row nb  2 .....................: FRd(2) =       13.30 kN

   moment resistance (weld failure disregarded) .....: MRdj   =      186.42 kNm
   moment resistance of the welds ...................: MRdw   =      316.76 kNm
                                                                  ---------
   moment resistance ..................... ( J.3.6 ) :               186.42 kNm

   elastic moment resistance ............. ( J.2.1.2 ) : Me     =      124.28 kNm
```

2.2.2 stiffness

2.2.2.1 determination of the equivalent stiffness coefficient

```
                        effective stiffness
                        coefficient (mm)          lever arm of internal forces
                        ( Form. J.36 )

   bolt row nb  1 : keff,1 =       2.74              h 1 =      496.00
   bolt row nb  2 : keff,2 =       2.73              h 2 =      381.00
```

```
lever arm of internal forces ....... ( Form. J.38 ) : z      =      446.19 mm
equivalent stiffness coefficient ... ( Form. J.36 ) : keq    =        5.37 mm
```

2.2.2.2 percentages of flexibility

```
the flexibility of each bolt row is the relative flexibility of each
bolt row in comparison with the other ones regardless of the lever arms

for the sheared panel                56 %
for the compression zone             14 %
for the tension zone                 30 %
   * bolt row nb 1                          50 %
        end plate in bending                              2 %
        bolts in tension                                 44 %
   * bolt row nb 2                          50 %
        end plate in bending                              3 %
        bolts in tension                                 44 %
```

2.2.2.3 summary

```
initial stiffness .................. ( Form. J.34 ) : Sji    =    67956.25 kNm/rad
idealized stiffness . ( J.2.1.2 - J.2.1.4 - T.J.3 ) : Sjn    =    33978.12 kNm/rad
secant stiffness ................... ( Form. J.34 ) : Sjs    =    22739.61 kNm/rad
```

2.2.3 shear resistance

```
shear resistance of one bolt row .. ( Table 6.5.3 ) : FvRd   =      282.40 kN


column flange in bearing ( Table 6.5.3 ):
                                                  p1/(3d0)-0.25 =        1.22
                                                  fub / fu      =        2.78
                                                  =>     ALPHA  =        1.00
   bearing resistance of one bolt row ..............: FbRd   =      566.78 kN

end plate in bearing ( Table 6.5.3 ):
                                                  e1/(3d0)      =        0.45
                                                  p1/(3d0)-0.25 =       -0.25
                                                  fub / fu      =        2.78
first bolt row ....................................: ALPHA  =        0.45
   bearing resistance .............................: FbRd   =      635.82 kN
other bolt rows ...................................: ALPHA  =       -0.25
   bearing resistance of one bolt row ..............: FbRd   =     -354.24 kN

the shear resistance of a bolt row submited to both
   shear and tensile forces is reduced by a factor 0.4/1.4
             ( J.3.1.2.(2b) )

shear resistance of the bolt row n°  1 ..........: Vrd(1) =       80.69 kN

shear resistance of the welds
   correlation factor ............. ( 6.6.5.3.(5) ) : BETA   =        0.80
   length of the weld ..............................: a      =      384.00 mm
   shear resistance of the welds .. ( 6.6.5.3.(4) ) : FwRd   =      798.13 kN

design shear resistance of the joint ..............: VRd    =     -273.55 kN
```

2.2.4 collapse mode

```
   bolt row nb 1 : column flange in bending
   bolt row nb 2 : column web panel in shear

   sufficient rotation capacity for plastic global analysis

*****   warning   *****
backing plates : requirement for length not satisfied ( J.3.2.3.(3) )
      minimum length ..................................: l     =      211.00 mm
```

2.3 DESIGN PROPERTIES OF THE JOINT FOR PLASTIC ANALYSIS / PLASTIC JOINT DESIGN

```
   design moment resistance ..........................: MRd    =      186.42 kNm

   initial stiffness .................. ( Form. J.34 ) : Sji    =    67956.25 kNm/rad
   idealized stiffness . ( J.2.1.2 - J.2.1.4 - T.J.3 ) : Sjn    =    33978.12 kNm/rad
```

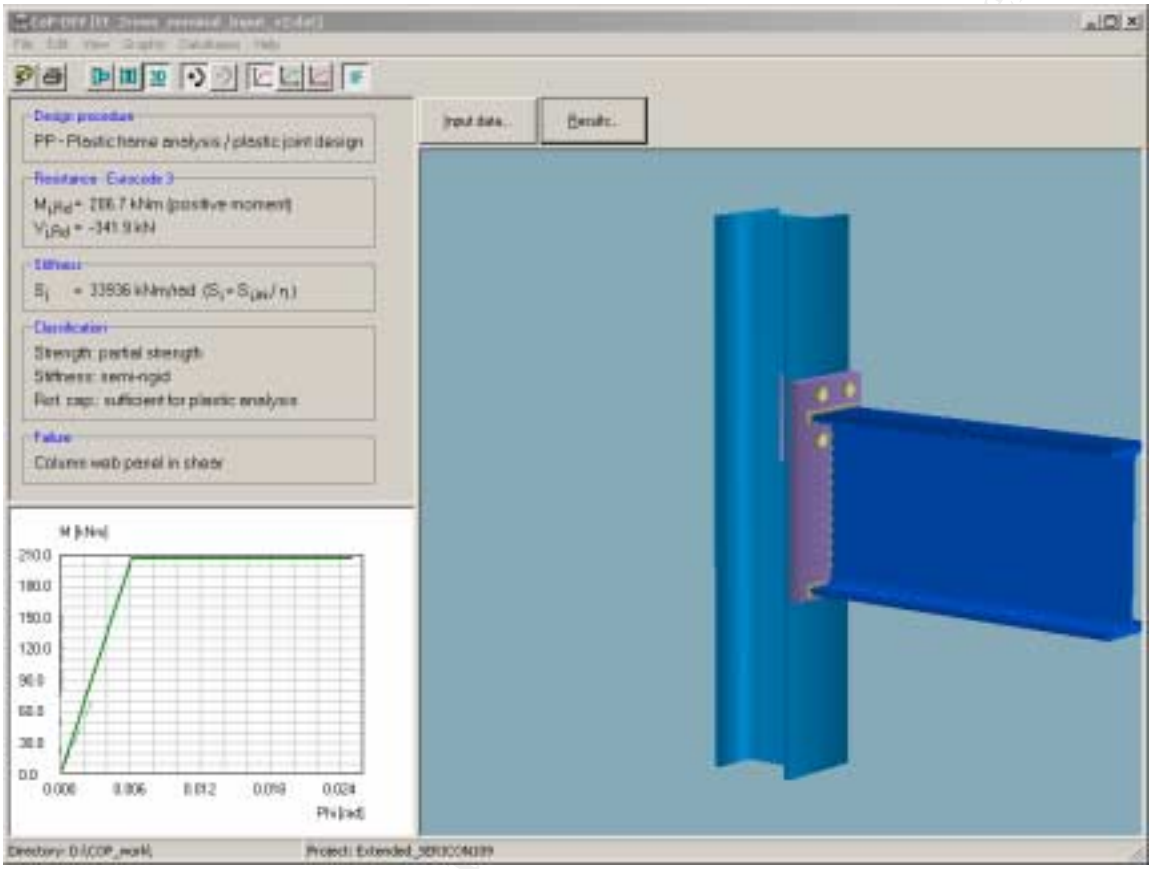
3. References

[1] ENV 1993-1-1 : 1992, Eurocode 3: Design of steel structures.
Part 1.1: General rules and rules for buildings,
CEN, Brussels 1992.

[2] ENV 1993-1-1 : 1992/A2, October 1998.
Revised Annex J of Eurocode 3, "Joints in Building Frames",
CEN, Brussels, October 1998.

SERICON 109005, nominal properties, no safety factors

Design of joints in building frames
according to Eurocode 3 - revised Annex J



1. INPUT DATA

1.1 PROJECT DATA

```
project ....................: MSC in Civil Engineering - Structures
structure ..................: SERICON 109005 Nominal
joint ......................: Extended End-plate
joint id ...................: 109005
engineer ...................: LB
date .......................: 28-03-2003

design procedure ...........: plastic analysis / plastic joint design

environment ................: not corrosive
framing ....................: not braced
```

1.2 main joint data

```
beam :                    IPE 450,  S 235
column :                  HEB 240,  S 235
extended end plate :      553 X 239 X 41,  S 235

backing plates
```

1.3 mechanical characteristics

	yield strength N/mm²	ultimate strength N/mm²
beam web	235.00	360.00
beam flange	235.00	360.00
column web	235.00	360.00
column flange	235.00	360.00
end plate	235.00	360.00
bolts in tension	900.00	1000.00
backing plates	235.00	

1.4 geometrical characteristics

1.4.1 beam : IPE 450, S 235

depth	454.00 mm
width	192.00 mm
thickness of the flange	14.00 mm
thickness of the web	10.40 mm
root radius	21.00 mm
inertia	34371.97 cm4
area	101.85 cm²
length of the beam connected to the column	693.00 mm
beam inclination	0.00 °

1.4.2 column : HEB 240, S 235

depth	242.00 mm
width	240.00 mm
thickness of the flange	16.40 mm
thickness of the web	10.40 mm
root radius	21.00 mm
inertia	11205.79 cm4
area	104.26 cm²

1.4.3 end plate 553 X 239 X 41, S 235

vertical distance between the beam flange and the edge of the end plate	84.00 mm
vertical distance between the first bolt row and the edge of the end plate	35.00 mm
vertical distance between the bolt rows 1 and 2	115.00 mm
horizontal distance between the bolts	109.00 mm
horizontal distance between the bolts and the edge of the end plate	65.00 mm

1.4.4 backing plates

thickness of the plate		12.00 mm
width of the plate		92.00 mm
length of the plate		219.00 mm
yield strength		235.00 N/mm²

1.4.5 bolts in tension 10.9

resistant area		353.00 mm²
diameter of the shank		24.00 mm
diameter of the holes		26.00 mm
thickness of the bolt head		15.00 mm
thickness of the nut		19.00 mm
total thickness of the washer(s) per bolt		4.00 mm
diameter of the washers		44.00 mm

1.4.6 welds

thickness of the weld connecting the beam flange		8.02 mm
thickness of the weld connecting the beam web		5.00 mm

1.5 safety factors

gamma M0		1.00
gamma M1		1.00
gamma Mb		1.00
gamma Mw		1.00

2. JOINT PROPERTIES FOR POSITIVE MOMENTS

2.1 CALCULATION OF THE COMPONENTS

2.1.1 column web panel in shear

sheared area of the column	Avc =	34.14	cm²
beta coefficient (J.2.6.3)	BETA =	1.00	
plastic resistance of the column web panel (J.3.5.1)	VwpRd =	416.83	kN
resistance : vwprd / beta	FwpRd =	416.83	kN
stiffness coefficient (Form. J.39)	k1 =	2.91	mm

2.1.2 column web in compression

effective width (Form. J.20)	l1 =	305.68	mm
	l2 =	268.34	mm
	=> beff =	268.34	mm
coefficient for stress interaction .. (Table J.5)	RHO =	0.73	
longitudinal compressive stress in the web adjacent to the root radius	Sigma =	0.00	N/mm²

```
reduction factor ..................... ( Form. J.22 ) : kwc    =        1.00

strength : ( Form. J.17 )
   * buckling of the web :
     slenderness ..................................: LAMBDA =        0.63
     strength .....................................: Fc2    =      479.73 kN

strength ..........................................: FcwcRd =      479.73 kN

stiffness coefficient ............... ( Form. J.40 ) : k2     =       11.68 mm
```

2.1.3 column flange in bending

```
geometrical parameters ............... ( Fig. J.25 ) : e      =       65.50 mm
======================                                 emin   =       65.00 mm
                                                       m      =       32.50 mm
                                                       n      =       40.62 mm
                                                       ew     =       11.00 mm
```

2.1.3.1 effective length of the equivalent t-stub (Tables J.6 - J.7)

```
   * circular patterns :
        2 Pi m ...................................: l      =      204.20 mm
   * other patterns :
        4 m + 1.25 e .............................: l      =      211.87 mm

   for all bolt rows :
   * circular patterns ..........................: leff   =      204.20 mm
   * other patterns .............................: leff   =      211.87 mm
```

2.1.3.2 strength

```
( J.3.5.4.2 )
design resistance of a bolt ....... ( Table 6.5.3 ) : BtRd   =      317.70 kN

*  bolt row nb 1

   longitudinal compressive stress in the flange ...: Sigma  =        0.00 N/mm²
   reduction factor ................. ( Form. J.29 ) : kfc    =        1.00

   mode of collapse for equivalent T-stub ( J.3.2.1 )

   design plastic resistance of the T-stub ( Form. J.7 )
      for complete yielding of the flange ...........: Mpl1Rd =     3226.70 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =     3347.92 Nm
   design moment resistance for the backing plates .: MbpRd  =     1727.56 Nm

   mode 1 : complete yielding of the flange ........: F1Rd   =      503.44 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      444.57 kN
   mode 3 : bolts failure ..........................: F3Rd   =      635.40 kN
            ( Form. J.9 - J.5 - J.6 )

   strength .....................................: FtRd(1)  =      444.57 kN
```

2.1.3.3 stiffness

```
*  effective length of the equivalent t-stub
```

```
   bolt rows are considered individually or as part of a group

   bolt row nb  1 ..............................: beff(1)  =      163.44 mm
   bolt row nb  2 ..............................: beff(2)  =      163.44 mm

*  stiffness coefficient ( Form. J.42 )

   bolt row nb  1 ..............................: k3(1)    =       17.85 mm
   bolt row nb  2 ..............................: k3(2)    =       17.85 mm
```

2.1.4 column web in tension

2.1.4.1 strength

bolt row nb	coefficient for stress interaction (Table J.5)	strength (kN)
1	0.81	417.05

2.1.4.2 stiffness

```
   bolt row nb  1 ..............................: k4(1)    =        7.12 mm
   bolt row nb  2 ..............................: k4(2)    =        7.12 mm
```

2.1.5 end plate in bending

```
   geometrical parameters ..............  ( Fig. J.28 ) : e      =       65.50 mm
   ======================                                 m      =       43.64 mm
                                                          ex     =       35.00 mm
                                                          mx     =       39.93 mm

   bolt row nb 2 ( below the top beam flange ) .....: m1     =       43.64 mm
                                                          m2     =       42.93 mm
      determination of the alpha coefficient .......: Lambda1=        0.40
         ( Fig. J.27 )                                 Lambda2=        0.40
                                                          ALPHA  =        6.59

   bolt row nb 2 ( up to the bottom beam flange ) ..: m1     =       43.64 mm
                                                          m2     =      364.93 mm
      determination of the alpha coefficient .......: Lambda1=        0.40
         ( Fig. J.27 )                                 Lambda2=        3.36
                                                          ALPHA  =        5.85
```

2.1.5.1 effective length of the equivalent t-stub (Tables J.8) :

```
   bolt row nb 1

   * circular patterns :
        2 Pi mx ..................................: l      =      250.87 mm
        Pi mx + w ................................: l      =      234.43 mm
        Pi mx + 2 e ..............................: l      =      255.43 mm
   * other patterns :
        4 mx + 1.25 ex ...........................: l      =      203.46 mm
        e + 2 mx + 0.625 ex ......................: l      =      166.73 mm
        0.5 w + 2 mx + 0.625 ex ..................: l      =      156.23 mm
        0.5 Bep ..................................: l      =      119.50 mm
```

```
   => effective length :
   * circular patterns ..............................: leff   =      234.43 mm
   * other patterns .................................: leff   =      119.50 mm

   bolt row nb 2 ( influence of the upper beam flange )
   * circular patterns :
        2 Pi m1 .....................................: leff   =      274.22 mm
   * other patterns :
        Alpha m1 ....................................: leff   =      287.70 mm

   bolt row nb 3 ( not influenced by the beam flanges )
   * circular patterns :
        2 Pi m1 .....................................: leff   =        0.00 mm
   * other patterns :
        4 m1 + 1.25 e ...............................: leff   =        0.00 mm

   bolt row nb 2 ( influence of the lower beam flange )
   * circular patterns :
        2 Pi m1 .....................................: leff   =      274.22 mm
   * other patterns :
        Alpha m1 ....................................: leff   =      287.70 mm
```

2.1.5.2 strength

```
*  bolt row nb 1

   mode of collapse for equivalent T-stub ( J.3.2.1 )

   design plastic resistance of the T-stub ( Form. J.7 )
      for complete yielding of the flange ..........: Mpl1Rd =    11801.67 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =    11801.67 Nm

   mode 1 : complete yielding of the flange .........: F1Rd   =     1182.34 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      611.83 kN
   mode 3 : bolts failure ..........................: F3Rd   =      635.40 kN
            ( Form. J.4 - J.5 - J.6 )

   strength ........................................: FtepRd(1)=      611.83 kN
```

2.1.5.3 stiffness

```
*  effective length of the equivalent t-stub
   bolt rows are considered individually or as part of a group

   bolt row nb  1 ..................................: leff(1) =      119.50 mm
   bolt row nb  2 ..................................: leff(2) =      137.11 mm

*  stiffness coefficient ( Form. J.43 )

   bolt row nb  1 ..................................: k5(1)  =      109.99 mm
   bolt row nb  2 ..................................: k5(2)  =       96.62 mm
```

2.1.5.4 bolts in tension

```
length of the bolt .................. ( J.4.4.10 ) : Lb     =       90.40 mm
strength ........................... ( Table 6.5.3 ) : BtRd   =      317.70 kN
stiffness coefficient .............. ( Form. J.45 ) : k7     =        6.25 mm
```

2.1.6 beam flange in compression

```
moment resistance of the beam cross-section ........: McRd   =     407.35 kNm
strength ........................... ( Form. J.30 ) : FcfbRd =     925.80 kN
```

2.1.7 beam web in tension

```
effective width
   => equal to the ones of the end plate in bending
```

2.1.7.1 strength

bolt row nb	strength (kN) (Form. J.31) FtwbRd(i)

2.2 ASSEMBLY OF THE COMPONENTS

2.2.1 strength (Fig. J.34)

2.2.1.1 bolt row nb 1

```
                                                          strength (kN)

column web panel in shear ..................................:     416.83
column web in compression ..................................:     479.73
column flange in bending ...................................:     444.57
column web in tension ......................................:     417.05
end plate in bending .......................................:     611.83
bolts in tension ...........................................:     635.40
beam flange in compression .................................:     925.80
                                                              ---------
resistance of bolt row nb  1 ......................: Frd(1) =     416.83 kN


plastic distribution of the internal forces
```

2.2.1.2 summary

```
resistance of bolt row nb  1 ......................: FRd(1) =     416.83 kN
resistance of bolt row nb  2 ......................: FRd(2) =       0.00 kN

moment resistance (weld failure disregarded) .......: MRdj   =     206.75 kNm
moment resistance of the welds .....................: MRdw   =     352.05 kNm
                                                              ---------
moment resistance ..................... ( J.3.6 ) :               206.75 kNm

elastic moment resistance ............. ( J.2.1.2 ) : Me     =     137.83 kNm
```

2.2.2 stiffness

2.2.2.1 determination of the equivalent stiffness coefficient

```
                      effective stiffness
                      coefficient (mm)          lever arm of internal forces
                      ( Form. J.36 )

bolt row nb  1 : keff,1 =       2.73               h 1 =      496.00
bolt row nb  2 : keff,2 =       2.73               h 2 =      381.00

lever arm of internal forces ....... ( Form. J.38 ) : z      =      446.14 mm
equivalent stiffness coefficient ... ( Form. J.36 ) : keq    =        5.37 mm
```

2.2.2.2 percentages of flexibility

```
the flexibility of each bolt row is the relative flexibility of each
bolt row in comparison with the other ones regardless of the lever arms

for the sheared panel                 56 %
for the compression zone              14 %
for the tension zone                  30 %
   * bolt row nb 1                          50 %
        end plate in bending                              2 %
        bolts in tension                                 44 %
   * bolt row nb 2                          50 %
        end plate in bending                              3 %
        bolts in tension                                 44 %
```

2.2.2.3 summary

```
initial stiffness .................. ( Form. J.34 ) : Sji    =    67872.73 kNm/rad
idealized stiffness . ( J.2.1.2 - J.2.1.4 - T.J.3 ) : Sjn    =    33936.37 kNm/rad
secant stiffness ................... ( Form. J.34 ) : Sjs    =    22711.66 kNm/rad
```

2.2.3 shear resistance

```
shear resistance of one bolt row .. ( Table 6.5.3 ) : FvRd   =      353.00 kN


column flange in bearing ( Table 6.5.3 ):
                                                p1/(3d0)-0.25 =        1.22
                                                fub / fu      =        2.78
                                                =>     ALPHA  =        1.00
   bearing resistance of one bolt row ..............: FbRd   =      708.48 kN

end plate in bearing ( Table 6.5.3 ):
                                                e1/(3d0)      =        0.45
                                                p1/(3d0)-0.25 =       -0.25
                                                fub / fu      =        2.78
first bolt row ....................................: ALPHA  =        0.45
   bearing resistance .............................: FbRd   =      794.77 kN
other bolt rows ...................................: ALPHA  =       -0.25
   bearing resistance of one bolt row ..............: FbRd   =     -442.80 kN

the shear resistance of a bolt row submited to both
   shear and tensile forces is reduced by a factor 0.4/1.4
                ( J.3.1.2.(2b) )
```

```
   shear resistance of the bolt row n°  1 .........: Vrd(1) =      100.86 kN

   shear resistance of the welds
      correlation factor ............. ( 6.6.5.3.(5) ) : BETA   =       0.80
      length of the weld ..............................: a      =     384.00 mm
      shear resistance of the welds .. ( 6.6.5.3.(4) ) : FwRd   =     997.66 kN

   design shear resistance of the joint ..............: VRd    =    -341.94 kN
```

2.2.4 collapse mode

```
   bolt row nb 1 : column web panel in shear

   sufficient rotation capacity for plastic global analysis

*****   warning   *****
backing plates : requirement for length not satisfied ( J.3.2.3.(3) )
      minimum length ..................................: l      =     211.00 mm
```

2.3 DESIGN PROPERTIES OF THE JOINT FOR PLASTIC ANALYSIS / PLASTIC JOINT DESIGN

```
   design moment resistance ..........................: MRd    =      206.75 kNm

   initial stiffness ................. ( Form. J.34 ) : Sji    =    67872.73 kNm/rad
   idealized stiffness . ( J.2.1.2 - J.2.1.4 - T.J.3 ) : Sjn    =    33936.37 kNm/rad
```

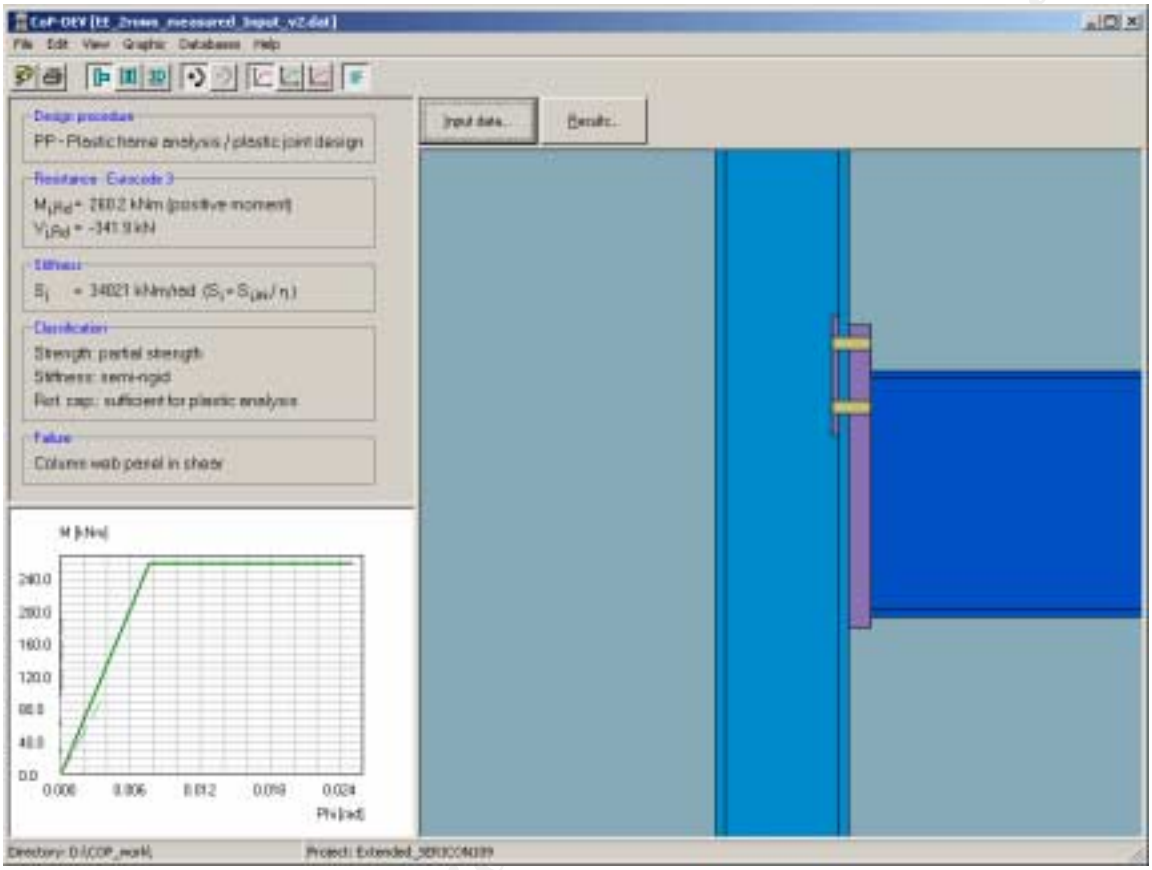
3. References

[1] ENV 1993-1-1 : 1992, Eurocode 3: Design of steel structures.
Part 1.1: General rules and rules for buildings,
CEN, Brussels 1992.

[2] ENV 1993-1-1 : 1992/A2, October 1998.
Revised Annex J of Eurocode 3, "Joints in Building Frames",
CEN, Brussels, October 1998.

SERICON 109005, measured properties, no safety factors

Design of joints in building frames
according to Eurocode 3 - revised Annex J



1. INPUT DATA

1.1 PROJECT DATA

```
project .....................: MSC in Civil Engineering - Structures
structure ...................: SERICON 109005 Measured
joint .......................: Extended End-plate
joint id ....................: 109005
engineer ....................: LB
date ........................: 28-03-2003

design procedure ............: plastic analysis / plastic joint design

environment .................: not corrosive
framing .....................: not braced
```

1.2 main joint data

```
beam :                    IPE 450,  S 235
column :                  HEB 240,  S 235
extended end plate :      553 X 239 X 41,  S 235

backing plates
```

1.3 mechanical characteristics

	yield strength N/mm²	ultimate strength N/mm²
beam web	315.60	360.00
beam flange	284.60	360.00
column web	306.60	360.00
column flange	275.90	360.00
end plate	323.00	360.00
bolts in tension	900.00	1000.00
backing plates	333.00	

1.4 geometrical characteristics

1.4.1 beam : IPE 450, S 235

depth	454.00 mm
width	192.00 mm
thickness of the flange	14.00 mm
thickness of the web	10.40 mm
root radius	21.00 mm
inertia	34371.97 cm4
area	101.85 cm²
length of the beam connected to the column	693.00 mm
beam inclination	0.00 °

1.4.2 column : HEB 240, S 235

depth	242.00 mm
width	240.00 mm
thickness of the flange	16.40 mm
thickness of the web	10.40 mm
root radius	21.00 mm
inertia	11205.79 cm4
area	104.26 cm²

1.4.3 end plate 553 X 239 X 41, S 235

vertical distance between the beam flange and the edge of the end plate	84.00 mm
vertical distance between the first bolt row and the edge of the end plate	35.00 mm
vertical distance between the bolt rows 1 and 2	115.00 mm
horizontal distance between the bolts	109.00 mm
horizontal distance between the bolts and the edge of the end plate	65.00 mm

1.4.4 backing plates

```
thickness of the plate ....................................:      12.00 mm
width of the plate ........................................:      92.00 mm
length of the plate .......................................:     219.00 mm
yield strength ............................................:     333.00 N/mm²
```

1.4.5 bolts in tension 10.9

```
resistant area ............................................:     353.00 mm²
diameter of the shank .....................................:      24.00 mm
diameter of the holes .....................................:      26.00 mm
thickness of the bolt head ................................:      15.00 mm
thickness of the nut ......................................:      19.00 mm
total thickness of the washer(s) per bolt .................:       4.00 mm
diameter of the washers ...................................:      44.00 mm
```

1.4.6 welds

```
thickness of the weld connecting the beam flange ..........:      10.08 mm
thickness of the weld connecting the beam web .............:       5.00 mm
```

1.5 safety factors

```
gamma M0 ..................................................:       1.00
gamma M1 ..................................................:       1.00
gamma Mb ..................................................:       1.00
gamma Mw ..................................................:       1.00
```

2. JOINT PROPERTIES FOR POSITIVE MOMENTS

2.1 CALCULATION OF THE COMPONENTS

2.1.1 column web panel in shear

```
sheared area of the column ..........................: Avc    =      34.14 cm²
beta coefficient ..................... ( J.2.6.3 ) : BETA   =       1.00
plastic resistance of the column web panel .........: VwpRd  =     543.83 kN
   ( J.3.5.1)
resistance : vwprd / beta ...........................: FwpRd  =     543.83 kN

stiffness coefficient .............. ( Form. J.39 ) : k1     =       2.91 mm
```

2.1.2 column web in compression

```
effective width ..................... ( Form. J.20 ) : l1     =     311.51 mm
                                                      l2     =     271.26 mm
                                                   => beff   =     271.26 mm

coefficient for stress interaction .. ( Table J.5 ) : RHO    =       0.73
longitudinal compressive stress in the web adjacent
   to the root radius ..............................: Sigma  =       0.00 N/mm²
reduction factor .................... ( Form. J.22 ) : kwc    =       1.00
```

```
strength : ( Form. J.17 )
   * buckling of the web :
     slenderness ..................................: LAMBDA =      0.73
     strength .....................................: Fc2    =    629.51 kN

strength .........................................: FcwcRd =    603.55 kN

stiffness coefficient ..... ( Form. J.40 ) : k2     =     11.81 mm
```

2.1.3 column flange in bending

```
geometrical parameters ..... ( Fig. J.25 ) : e      =     65.50 mm
======================                       emin   =     65.00 mm
                                             m      =     32.50 mm
                                             n      =     40.62 mm
                                             ew     =     11.00 mm
```

2.1.3.1 effective length of the equivalent t-stub (Tables J.6 - J.7)

```
1) bolts considered individually

   * circular patterns :
        2 Pi m ...................................: l      =    204.20 mm
   * other patterns :
        4 m + 1.25 e .............................: l      =    211.87 mm

   for all bolt rows :
   * circular patterns ..........................: leff   =    204.20 mm
   * other patterns .............................: leff   =    211.87 mm

2) bolts considered as part of a group

        group between bolt row nb
                                 circular patterns          other patterns
                                       (mm)                     (mm)

         1  -  2                       434.20                   326.8
```

2.1.3.2 strength

```
( J.3.5.4.2 )
design resistance of a bolt ..... ( Table 6.5.3 ) : BtRd   =    317.70 kN

1) bolts considered individually
   ----------------------------

*  bolt row nb 1

   longitudinal compressive stress in the flange ...: Sigma  =      0.00 N/mm²
   reduction factor ..... ( Form. J.29 ) : kfc    =      1.00

   mode of collapse for equivalent T-stub ( J.3.2.1 )

   design plastic resistance of the T-stub ( Form. J.7 )
      for complete yielding of the flange ..........: Mpl1Rd =   3788.28 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =   3930.60 Nm
```

```
   design moment resistance for the backing plates .: MbpRd  =     2447.99 Nm

   mode 1 : complete yielding of the flange ........: F1Rd   =      616.90 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      460.50 kN
   mode 3 : bolts failure ..........................: F3Rd   =      635.40 kN
            ( Form. J.9 - J.5 - J.6 )

   strength ........................................: FtRd(1)  =      460.50 kN

*  bolt row nb 2

   longitudinal compressive stress in the flange ...: Sigma  =        0.00 N/mm²
   reduction factor ................ ( Form. J.29 ) : kfc    =        1.00

   mode of collapse for equivalent T-stub ( J.3.2.1 )

   design plastic resistance of the T-stub ( Form. J.7 )
      for complete yielding of the flange ..........: Mpl1Rd =     3788.28 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =     3930.60 Nm
   design moment resistance for the backing plates .: MbpRd  =     2447.99 Nm

   mode 1 : complete yielding of the flange ........: F1Rd   =      616.90 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      460.50 kN
   mode 3 : bolts failure ..........................: F3Rd   =      635.40 kN
            ( Form. J.9 - J.5 - J.6 )

   strength ........................................: FtRd(2)  =      460.50 kN

2) bolts considered as part of a group
   ----------------------------------

*  group between bolt row nb 1 to nb 2

   longitudinal compressive stress in the flange ...: Sigma  =        0.00 N/mm²
   reduction factor ................ ( Form. J.29 ) : kfc    =        1.00

   mode of collapse for equivalent T-stub ( J.3.2.1 )

   design plastic resistance of the T-stub ( Form. J.7 )
      for complete yielding of the flange ..........: Mpl1Rd =     6064.03 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =     6064.03 Nm
   design moment resistance for the backing plates .: MbpRd  =     3918.58 Nm
            ( Form. J.10 )

   mode 1 : complete yielding of the flange ........: F1Rd   =      987.48 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      871.85 kN
   mode 3 : bolts failure ..........................: F3Rd   =     1270.80 kN
   strength ........................................: FtRd(1,2)=      871.85 kN
```

2.1.3.3 stiffness

```
*  effective length of the equivalent t-stub
   bolt rows are considered individually or as part of a group

   bolt row nb  1 ..................................: beff(1)  =      163.44 mm
   bolt row nb  2 ..................................: beff(2)  =      163.44 mm
```

```
*  stiffness coefficient ( Form. J.42 )

   bolt row nb  1 ..............................: k3(1)    =       17.85 mm
   bolt row nb  2 ..............................: k3(2)    =       17.85 mm
```

2.1.4 column web in tension

2.1.4.1 strength

bolt row nb	coefficient for stress interaction (Table J.5)	strength (kN)
1	0.81	544.11
2	0.81	544.11
group between bolt row nb		
1 - 2	0.66	688.87

2.1.4.2 stiffness

```
   bolt row nb  1 ..............................: k4(1)    =        7.12 mm
   bolt row nb  2 ..............................: k4(2)    =        7.12 mm
```

2.1.5 end plate in bending

```
geometrical parameters ..............  ( Fig. J.28 ) : e      =       65.50 mm
======================                                 m      =       43.64 mm
                                                       ex     =       35.00 mm
                                                       mx     =       37.60 mm

   bolt row nb 2 ( below the top beam flange ) .....: m1     =       43.64 mm
                                                       m2     =       40.60 mm
      determination of the alpha coefficient .......: Lambda1=        0.40
         ( Fig. J.27 )                                 Lambda2=        0.37
                                                       ALPHA  =        6.67

   bolt row nb 2 ( up to the bottom beam flange ) ..: m1     =       43.64 mm
                                                       m2     =      362.60 mm
      determination of the alpha coefficient .......: Lambda1=        0.40
         ( Fig. J.27 )                                 Lambda2=        3.34
                                                       ALPHA  =        5.85
```

2.1.5.1 effective length of the equivalent t-stub (Tables J.8) :

```
   bolt row nb 1

   * circular patterns :
        2 Pi mx ................................: l      =      236.22 mm
        Pi mx + w ..............................: l      =      227.11 mm
        Pi mx + 2 e ............................: l      =      248.11 mm
   * other patterns :
        4 mx + 1.25 ex .........................: l      =      194.13 mm
        e + 2 mx + 0.625 ex ....................: l      =      162.07 mm
        0.5 w + 2 mx + 0.625 ex ................: l      =      151.57 mm
        0.5 Bep ................................: l      =      119.50 mm
```

```
   => effective length :
   * circular patterns ..............................: leff   =      227.11 mm
   * other patterns .................................: leff   =      119.50 mm

   bolt row nb 2 ( influence of the upper beam flange )
   * circular patterns :
        2 Pi m1 .....................................: leff   =      274.22 mm
   * other patterns :
        Alpha m1 ....................................: leff   =      291.09 mm

   bolt row nb 3 ( not influenced by the beam flanges )
   * circular patterns :
        2 Pi m1 .....................................: leff   =        0.00 mm
   * other patterns :
        4 m1 + 1.25 e ...............................: leff   =        0.00 mm

   bolt row nb 2 ( influence of the lower beam flange )
   * circular patterns :
        2 Pi m1 .....................................: leff   =      274.22 mm
   * other patterns :
        Alpha m1 ....................................: leff   =      291.09 mm
```

2.1.5.2 strength

```
*  bolt row nb 1

   mode of collapse for equivalent T-stub ( J.3.2.1 )

   design plastic resistance of the T-stub ( Form. J.7 )
      for complete yielding of the flange ...........: Mpl1Rd =    16221.02 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =    16221.02 Nm

   mode 1 : complete yielding of the flange ........: F1Rd   =     1725.83 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      753.23 kN
   mode 3 : bolts failure ..........................: F3Rd   =      635.40 kN
            ( Form. J.4 - J.5 - J.6 )

   strength ........................................: FtepRd(1)=      635.40 kN

*  bolt row nb 2

   mode of collapse for equivalent T-stub ( J.3.2.1 )

   design plastic resistance of the T-stub ( Form. J.7 )
      for complete yielding of the flange ...........: Mpl1Rd =    37222.55 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =    39512.70 Nm

   mode 1 : complete yielding of the flange ........: F1Rd   =     3411.54 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =     1157.76 kN
   mode 3 : bolts failure ..........................: F3Rd   =      635.40 kN

   strength ........................................: FtepRd(2)=      635.40 kN
```

2.1.5.3 stiffness

```
*  effective length of the equivalent t-stub
   bolt rows are considered individually or as part of a group
```

```
   bolt row nb  1 ..............................: leff(1) =      119.50 mm
   bolt row nb  2 ..............................: leff(2) =      137.11 mm

*  stiffness coefficient ( Form. J.43 )

   bolt row nb  1 ..............................: k5(1)  =      131.74 mm
   bolt row nb  2 ..............................: k5(2)  =       96.62 mm
```

2.1.5.4 bolts in tension

```
length of the bolt .................. ( J.4.4.10 ) : Lb     =      90.40 mm
strength ........................... ( Table 6.5.3 ) : BtRd   =     317.70 kN
stiffness coefficient ............... ( Form. J.45 ) : k7     =       6.25 mm
```

2.1.6 beam flange in compression

```
moment resistance of the beam cross-section ........: McRd   =     515.44 kNm
strength ........................... ( Form. J.30 ) : FcfbRd =    1171.46 kN
```

2.1.7 beam web in tension

effective width
=> equal to the ones of the end plate in bending

2.1.7.1 strength

bolt row nb		strength (kN) (Form. J.31) FtwbRd(i)
2	:	955.43

2.2 ASSEMBLY OF THE COMPONENTS

2.2.1 strength (Fig. J.34)

2.2.1.1 bolt row nb 1

```
                                                              strength (kN)

column web panel in shear ..................................:     543.83
column web in compression ..................................:     603.55
column flange in bending ...................................:     460.50
column web in tension ......................................:     544.11
end plate in bending .......................................:     635.40
bolts in tension ...........................................:     635.40
beam flange in compression .................................:    1171.46
                                                              ---------
resistance of bolt row nb  1 ...................: Frd(1) =      460.50 kN
```

2.2.1.2 bolt row nb 2

```
                                                              strength (kN)
```

2.2.1.2.1 1) bolts considered individually

```
column web panel in shear ..................................:      83.33
column web in compression ..................................:     143.05
column flange in bending ...................................:     460.50
column web in tension ......................................:     544.11
end plate in bending .......................................:     635.40
bolts in tension ...........................................:     635.40
beam flange in compression .................................:     710.96
beam web in tension ........................................:     955.43
```

2.2.1.2.2 2) bolts considered as part of a group

```
group between bolt row nb 1 to nb 2

   column flange in bending ................................:     411.35
   column web in tension ...................................:     228.37

                                                              ---------
resistance of bolt row nb  2 .....................: Frd(2) =      83.33 kN


plastic distribution of the internal forces
```

2.2.1.3 summary

```
resistance of bolt row nb  1 .....................: FRd(1) =     460.50 kN
resistance of bolt row nb  2 .....................: FRd(2) =      83.33 kN

moment resistance (weld failure disregarded) .....: MRdj   =     260.16 kNm
moment resistance of the welds ...................: MRdw   =     442.48 kNm
                                                              ---------
moment resistance ..................... ( J.3.6 ) :              260.16 kNm

elastic moment resistance ............. ( J.2.1.2 ) : Me     =     173.44 kNm
```

2.2.2 stiffness

2.2.2.1 determination of the equivalent stiffness coefficient

```
                     effective stiffness
                     coefficient (mm)          lever arm of internal forces
                     ( Form. J.36 )

bolt row nb  1 : keff,1 =       2.75               h 1 =     496.00
bolt row nb  2 : keff,2 =       2.73               h 2 =     381.00

lever arm of internal forces ..... ( Form. J.38 ) : z      =     446.25 mm
equivalent stiffness coefficient ... ( Form. J.36 ) : keq    =       5.38 mm
```

2.2.2.2 percentages of flexibility

```
the flexibility of each bolt row is the relative flexibility of each
bolt row in comparison with the other ones regardless of the lever arms

for the sheared panel                56 %
```

```
for the compression zone              14 %
for the tension zone                  30 %
   * bolt row nb 1                           50 %
        end plate in bending                                  2 %
        bolts in tension                                     44 %
   * bolt row nb 2                           50 %
        end plate in bending                                  3 %
        bolts in tension                                     44 %
```

2.2.2.3 summary

```
initial stiffness ................. ( Form. J.34 ) : Sji    =    68042.34 kNm/rad
idealized stiffness . ( J.2.1.2 - J.2.1.4 - T.J.3 ) : Sjn    =    34021.17 kNm/rad
secant stiffness .................. ( Form. J.34 ) : Sjs    =    22768.42 kNm/rad
```

2.2.3 shear resistance

```
shear resistance of one bolt row .. ( Table 6.5.3 ) : FvRd   =      353.00 kN


column flange in bearing ( Table 6.5.3 ):
                                                  p1/(3d0)-0.25 =        1.22
                                                  fub / fu      =        2.78
                                                  =>     ALPHA  =        1.00
   bearing resistance of one bolt row ..............: FbRd   =      708.48 kN

end plate in bearing ( Table 6.5.3 ):
                                                  e1/(3d0)      =        0.45
                                                  p1/(3d0)-0.25 =       -0.25
                                                  fub / fu      =        2.78
first bolt row ....................................: ALPHA  =        0.45
   bearing resistance .............................: FbRd   =      794.77 kN
other bolt rows ...................................: ALPHA  =       -0.25
   bearing resistance of one bolt row ..............: FbRd   =     -442.80 kN

the shear resistance of a bolt row submited to both
   shear and tensile forces is reduced by a factor 0.4/1.4
                ( J.3.1.2.(2b) )

shear resistance of the bolt row n°  1 .........: Vrd(1) =      100.86 kN

shear resistance of the welds
   correlation factor ............. ( 6.6.5.3.(5) ) : BETA   =        0.80
   length of the weld .............................: a      =      384.00 mm
   shear resistance of the welds .. ( 6.6.5.3.(4) ) : FwRd   =      997.66 kN

design shear resistance of the joint ..............: VRd    =     -341.94 kN
```

2.2.4 collapse mode

```
bolt row nb 1 : column flange in bending
bolt row nb 2 : column web panel in shear

sufficient rotation capacity for plastic global analysis

*****   warning   *****
```

```
backing plates : requirement for length not satisfied ( J.3.2.3.(3) )
      minimum length ..................................: l      =      211.00 mm
```

2.3 DESIGN PROPERTIES OF THE JOINT FOR PLASTIC ANALYSIS / PLASTIC JOINT DESIGN

```
   design moment resistance ..........................: MRd    =      260.16 kNm

   initial stiffness ................. ( Form. J.34 ) : Sji    =    68042.34 kNm/rad
   idealized stiffness . ( J.2.1.2 - J.2.1.4 - T.J.3 ) : Sjn    =    34021.17 kNm/rad
```

3. References

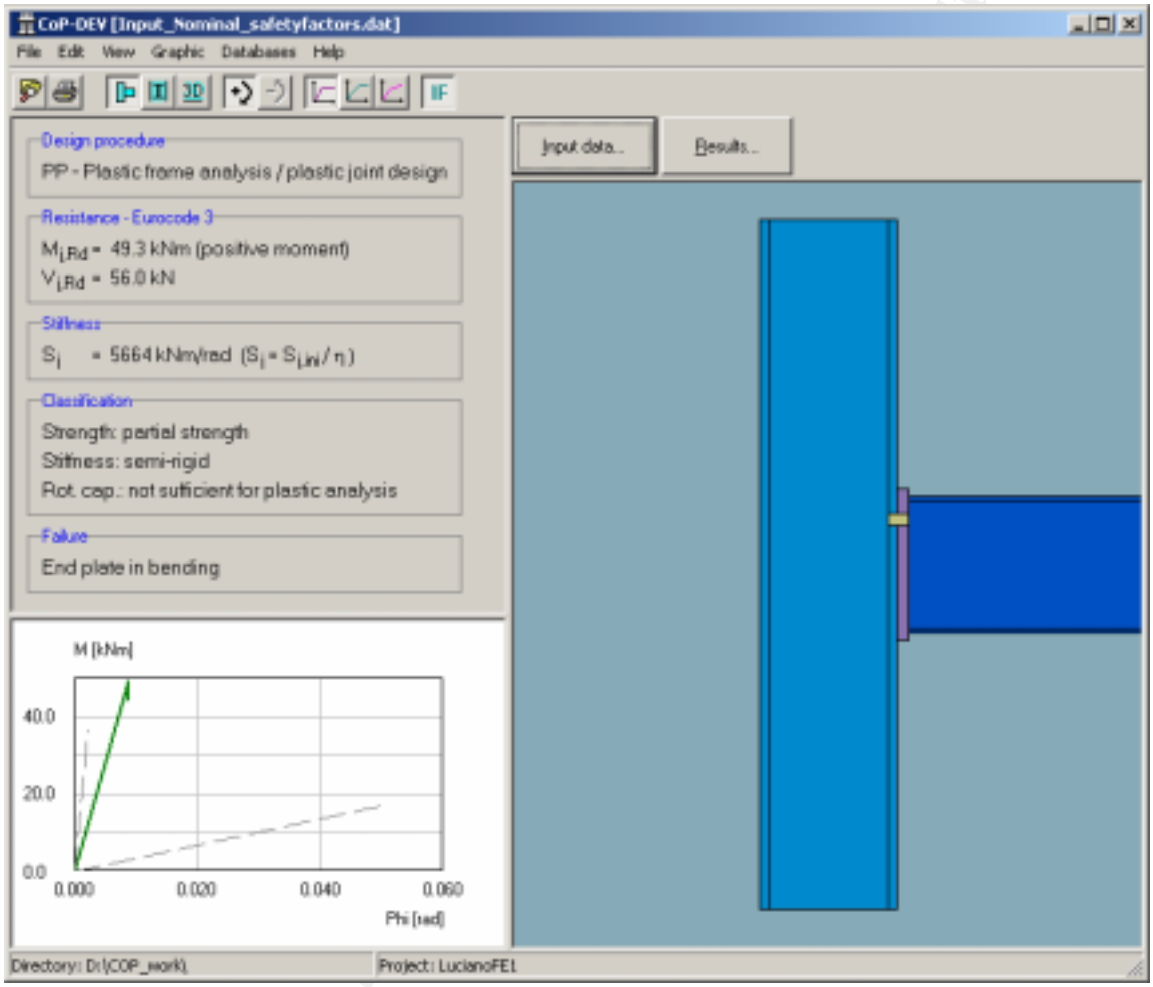
[1] ENV 1993-1-1 : 1992, Eurocode 3: Design of steel structures.
Part 1.1: General rules and rules for buildings,
CEN, Brussels 1992.

[2] ENV 1993-1-1 : 1992/A2, October 1998.
Revised Annex J of Eurocode 3, "Joints in Building Frames",
CEN, Brussels, October 1998.

FE1 Lima's Flush Endplate Joint

FE1, nominal properties, safety factors

Design of joints in building frames
according to Eurocode 3 - revised Annex J



1. INPUT DATA

1.1 PROJECT DATA

```
project ....................: MSc in Civil Engineering - Structures
structure ..................: FE1
joint ......................: Flush End Plate Tested by Luciano Lima in Coimbra
joint id ...................: FE1 - Nominal + safety factors
engineer ...................: LB
```

```
date .......................: 28-03-2003

design procedure ............: plastic analysis / plastic joint design

environment ................: not corrosive
framing ....................: not braced
```

1.2 main joint data

```
beam :                  IPE 240,  S 275
column :                HEB 240,  S 275
flush end plate :       264 X 160 X 15,  S 275
```

1.3 mechanical characteristics

	yield strength N/mm²	ultimate strength N/mm²
beam web	275.00	430.00
beam flange	275.00	430.00
column web	275.00	430.00
column flange	275.00	430.00
end plate	275.00	430.00
bolts in tension	900.00	1000.00

1.4 geometrical characteristics

1.4.1 beam : IPE 240, S 275

```
depth ..................................................:     240.00 mm
width ..................................................:     120.00 mm
thickness of the flange ................................:       9.80 mm
thickness of the web ...................................:       6.20 mm
root radius ............................................:      15.00 mm
inertia ................................................:    3891.63 cm4
area ...................................................:      39.12 cm²
length of the beam connected to the column .............:    6000.00 mm
beam inclination .......................................:       0.00 °
```

1.4.2 column : HEB 240, S 275

```
depth ..................................................:     240.00 mm
width ..................................................:     240.00 mm
thickness of the flange ................................:      17.00 mm
thickness of the web ...................................:      10.00 mm
root radius ............................................:      21.00 mm
inertia ................................................:   11259.30 cm4
area ...................................................:     105.99 cm²
```

1.4.3 end plate 264 X 160 X 15, S 275

```
vertical distance between the beam flange and the edge
   of the end plate ....................................:      12.00 mm
vertical distance between the first bolt row and the
   edge of the end plate ...............................:      54.00 mm
horizontal distance between the bolts ..................:      96.00 mm
```

horizontal distance between the bolts and the edge
of the end plate .....: 32.00 mm

1.4.4 bolts in tension 10.9

resistant area .....: 245.00 mm²
diameter of the shank .....: 20.00 mm
diameter of the holes .....: 22.00 mm
thickness of the bolt head .....: 13.00 mm
thickness of the nut .....: 16.00 mm
total thickness of the washer(s) per bolt .....: 4.00 mm
diameter of the washers .....: 37.00 mm

1.4.5 welds

thickness of the weld connecting the beam flange .....: 8.00 mm
thickness of the weld connecting the beam web .....: 8.00 mm

1.5 safety factors

gamma M0 .....: 1.10
gamma M1 .....: 1.10
gamma Mb .....: 1.25
gamma Mw .....: 1.25

2. JOINT PROPERTIES FOR POSITIVE MOMENTS

2.1 CALCULATION OF THE COMPONENTS

2.1.1 column web panel in shear

sheared area of the column .....: Avc = 33.23 cm²
beta coefficient ..... (J.2.6.3) : BETA = 1.00
plastic resistance of the column web panel .....: VwpRd = 431.61 kN
(J.3.5.1)
resistance : vwprd / beta .....: FwpRd = 431.61 kN

stiffness coefficient ..... (Form. J.39) : k1 = 6.54 mm

2.1.2 column web in compression

effective width ..... (Form. J.20) : l1 = 252.43 mm
l2 = 238.11 mm
=> beff = 238.11 mm

coefficient for stress interaction .. (Table J.5) : RHO = 0.77
longitudinal compressive stress in the web adjacent
to the root radius .....: Sigma = 0.00 N/mm²
reduction factor ..... (Form. J.22) : kwc = 1.00

strength : (Form. J.17)
* buckling of the web :

```
      slenderness ....................................: LAMBDA =        0.67
      strength .......................................: Fc2    =      460.97 kN

   strength ..........................................: FcwcRd =      460.97 kN

   stiffness coefficient .............. ( Form. J.40 ) : k2     =       10.16 mm
```

2.1.3 column flange in bending

```
   geometrical parameters .............. ( Fig. J.25 ) : e      =       72.00 mm
   ======================                               emin   =       32.00 mm
                                                        m      =       26.20 mm
                                                        n      =       32.00 mm
                                                        ew     =        9.25 mm
```

2.1.3.1 effective length of the equivalent t-stub (Tables J.6 - J.7)

```
      * circular patterns :
           2 Pi m .....................................: l      =      164.62 mm
      * other patterns :
           4 m + 1.25 e ...............................: l      =      194.80 mm

      for all bolt rows :
      * circular patterns ..............................: leff   =      164.62 mm
      * other patterns .................................: leff   =      194.80 mm
```

2.1.3.2 strength

```
   ( J.3.5.4.2 )
   design resistance of a bolt ....... ( Table 6.5.3 ) : BtRd   =      176.40 kN

   *  bolt row nb 1

      longitudinal compressive stress in the flange ...: Sigma  =        0.00 N/mm²
      reduction factor ..... ( Form. J.29 ) : kfc    =        1.00

      mode of collapse for equivalent T-stub ( J.3.2.1 )

      design plastic resistance of the T-stub ( Form. J.7 )
         for complete yielding of the flange ..........: Mpl1Rd =     2973.44 Nm
         for bolt failure with yielding of the flange .: Mpl2Rd =     3518.57 Nm

      mode 1 : complete yielding of the flange ........: F1Rd   =      453.96 kN
      mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      314.89 kN
      mode 3 : bolts failure ..........................: F3Rd   =      352.80 kN
               ( Form. J.4 - J.5 - J.6 )

      strength .....................................: FtRd(1)  =      314.89 kN
```

2.1.3.3 stiffness

```
   *  effective length of the equivalent t-stub
      bolt rows are considered individually or as part of a group

      bolt row nb  1 ..............................: beff(1)  =      164.62 mm

   *  stiffness coefficient ( Form. J.42 )
```

```
     bolt row nb  1 ..............................: k3(1)    =       38.22 mm
```

2.1.4 column web in tension

2.1.4.1 strength

bolt row nb	coefficient for stress interaction (Table J.5)	strength (kN)
1	0.83	404.87

2.1.4.2 stiffness

```
     bolt row nb  1 ..............................: k4(1)    =        7.03 mm
```

2.1.5 end plate in bending

```
   geometrical parameters ..... ( Fig. J.28 ) : e      =       72.00 mm
   ======================                       m      =       35.85 mm

      bolt row nb 1 ( below the top beam flange ) .....: m1     =       35.85 mm
                                                        m2     =       23.15 mm
         determination of the alpha coefficient .......: Lambda1=        0.53
            ( Fig. J.27 )                               Lambda2=        0.34
                                                        ALPHA  =        5.98

      bolt row nb 1 ( up to the bottom beam flange ) ..: m1     =       35.85 mm
                                                        m2     =      179.15 mm
         determination of the alpha coefficient .......: Lambda1=        0.53
            ( Fig. J.27 )                               Lambda2=        2.64
                                                        ALPHA  =        5.13
```

2.1.5.1 effective length of the equivalent t-stub (Tables J.8) :

```
      bolt row nb 1 ( influence of the upper beam flange )
      * circular patterns :
           2 Pi m1 ..................................: leff   =      225.25 mm
      * other patterns :
           Alpha m1 .................................: leff   =      214.48 mm

      bolt row nb 2 ( not influenced by the beam flanges )
      * circular patterns :
           2 Pi m1 ..................................: leff   =        0.00 mm
      * other patterns :
           4 m1 + 1.25 e ............................: leff   =        0.00 mm

      bolt row nb 1 ( influence of the lower beam flange )
      * circular patterns :
           2 Pi m1 ..................................: leff   =      225.25 mm
      * other patterns :
           Alpha m1 .................................: leff   =      214.48 mm
```

2.1.5.2 strength

```
   *  bolt row nb 1
```

```
   mode of collapse for equivalent T-stub ( J.3.2.1 )

   design plastic resistance of the T-stub ( Form. J.7 )
      for complete yielding of the flange ..........: Mpl1Rd =     3016.08 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =     3016.08 Nm

   mode 1 : complete yielding of the flange ........: F1Rd   =      336.53 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      255.30 kN
   mode 3 : bolts failure ..........................: F3Rd   =      352.80 kN
            ( Form. J.4 - J.5 - J.6 )

   strength ....................................: FtepRd(1)=      255.30 kN
```

2.1.5.3 stiffness

```
   *  effective length of the equivalent t-stub
      bolt rows are considered individually or as part of a group

      bolt row nb  1 ..............................: leff(1) =      112.62 mm

   *  stiffness coefficient ( Form. J.43 )

      bolt row nb  1 ..............................: k5(1)  =        7.01 mm
```

2.1.5.4 bolts in tension

```
   length of the bolt ................... ( J.4.4.10 ) : Lb     =       50.50 mm
   strength ........................... ( Table 6.5.3 ) : BtRd   =      176.40 kN
   stiffness coefficient .............. ( Form. J.45 ) : k7     =        7.76 mm
```

2.1.6 beam flange in compression

```
   moment resistance of the beam cross-section .........: McRd   =       91.66 kNm
   strength ........................... ( Form. J.30 ) : FcfbRd =      398.18 kN
```

2.1.7 beam web in tension

```
   effective width
      => equal to the ones of the end plate in bending
```

2.1.7.1 strength

bolt row nb	strength (kN) (Form. J.31) FtwbRd(i)
1 :	332.44

2.2 ASSEMBLY OF THE COMPONENTS

2.2.1 strength (Fig. J.34)

2.2.1.1 bolt row nb 1

```
                                                                strength (kN)

   column web panel in shear ..................................:     431.61
   column web in compression ..................................:     460.97
   column flange in bending ...................................:     314.89
   column web in tension ......................................:     404.87
   end plate in bending .......................................:     255.30
   bolts in tension ...........................................:     352.80
   beam flange in compression .................................:     398.18
   beam web in tension ........................................:     332.44
                                                                   ---------
   resistance of bolt row nb  1 ......................: Frd(1) =     255.30 kN


plastic distribution of the internal forces
```

2.2.1.2 summary

```
   resistance of bolt row nb  1 ......................: FRd(1) =     255.30 kN

   moment resistance (weld failure disregarded) ......: MRdj   =      49.30 kNm
   moment resistance of the welds ....................: MRdw   =     103.27 kNm
                                                                   ---------
   moment resistance ..................... ( J.3.6 ) :               49.30 kNm

   elastic moment resistance ............. ( J.2.1.2 ) : Me     =      32.87 kNm
```

2.2.2 stiffness

2.2.2.1 determination of the equivalent stiffness coefficient

```
                        effective stiffness
                        coefficient (mm)          lever arm of internal forces
                        ( Form. J.36 )

   bolt row nb  1 : keff,1 =      2.27               h 1 =      193.10

   lever arm of internal forces ....... ( Form. J.38 ) : z      =     193.10 mm
   equivalent stiffness coefficient ... ( Form. J.36 ) : keq    =       2.27 mm
```

2.2.2.2 percentages of flexibility

```
   the flexibility of each bolt row is the relative flexibility of each
   bolt row in comparison with the other ones regardless of the lever arms

   for the sheared panel                22 %
   for the compression zone             14 %
   for the tension zone                 64 %
      * bolt row nb 1                          ** %
           end plate in bending                                  32 %
           bolts in tension                                      29 %
```

2.2.2.3 summary

```
   initial stiffness .................. ( Form. J.34 ) : Sji    =    11328.06 kNm/rad
```

```
   idealized stiffness . ( J.2.1.2 - J.2.1.4 - T.J.3 ) : Sjn    =     5664.03 kNm/rad
   secant stiffness ..................... ( Form. J.34 ) : Sjs    =     3790.61 kNm/rad
```

2.2.3 shear resistance

```
   shear resistance of one bolt row .. ( Table 6.5.3 ) : FvRd   =      196.00 kN


   column flange in bearing ( Table 6.5.3 ):
                                                 p1/(3d0)-0.25 =      151.27
                                                 fub / fu      =        2.33
                                                 =>     ALPHA  =        1.00
      bearing resistance of one bolt row ..............: FbRd   =      584.80 kN

   end plate in bearing :
                                                 p1/(3d0)-0.25 =      151.27
                                                 fub / fu      =        2.33
                                                 =>     ALPHA  =        1.00
      bearing resistance of one bolt row ..............: FbRd   =      489.73 kN

   the shear resistance of a bolt row submited to both
      shear and tensile forces is reduced by a factor 0.4/1.4
                  ( J.3.1.2.(2b) )

   shear resistance of the bolt row n°  1 ..........: Vrd(1) =       56.00 kN

   shear resistance of the welds
      correlation factor ............. ( 6.6.5.3.(5) ) : BETA   =        0.85
      length of the weld ..............................: a      =      190.40 mm
      shear resistance of the welds .. ( 6.6.5.3.(4) ) : FwRd   =      711.81 kN

   design shear resistance of the joint ...............: VRd    =       56.00 kN
```

2.2.4 collapse mode

```
   bolt row nb 1 : end plate in bending

   not enough rotation capacity for plastic global analysis
```

2.3 DESIGN PROPERTIES OF THE JOINT FOR PLASTIC ANALYSIS / PLASTIC JOINT DESIGN

```
   design moment resistance ............................: MRd    =       49.30 kNm

   initial stiffness ..................... ( Form. J.34 ) : Sji    =    11328.06 kNm/rad
   idealized stiffness . ( J.2.1.2 - J.2.1.4 - T.J.3 ) : Sjn    =     5664.03 kNm/rad
```

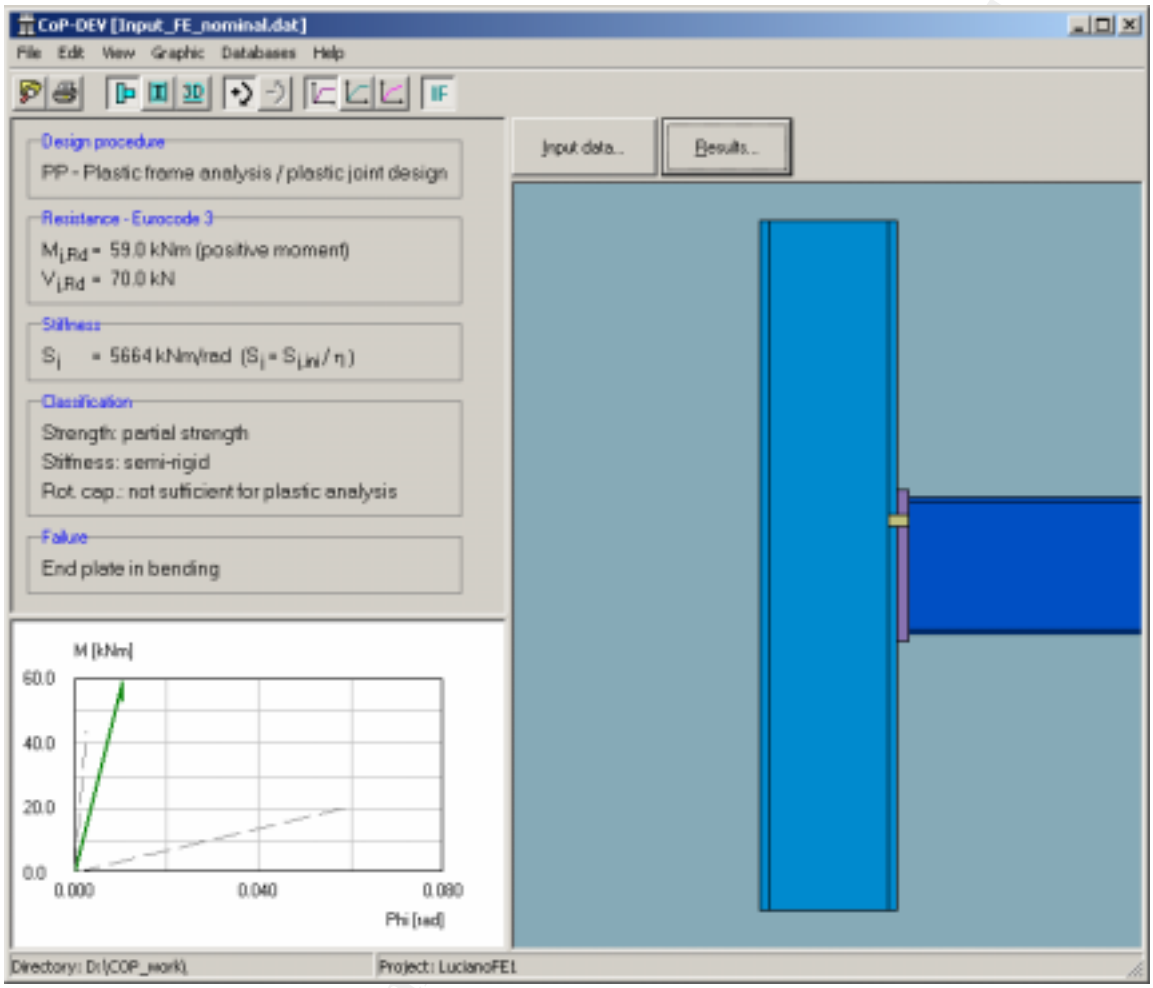
3. References

[1] ENV 1993-1-1 : 1992, Eurocode 3: Design of steel structures.
Part 1.1: General rules and rules for buildings,
CEN, Brussels 1992.

[2] ENV 1993-1-1 : 1992/A2, October 1998.
Revised Annex J of Eurocode 3, "Joints in Building Frames",
CEN, Brussels, October 1998.

FE1, nominal properties, no safety factors

Design of joints in building frames
according to Eurocode 3 - revised Annex J



1. INPUT DATA

1.1 PROJECT DATA

```
project .....................: MSc in Civil Engineering - Structures
structure ...................: FE1
joint .......................: Flush End Plate Tested by Luciano Lima in Coimbra
joint id ....................: FE1 - Nominal
engineer ....................: LB
date ........................: 28-03-2003

design procedure ............: plastic analysis / plastic joint design
```

environment .....: not corrosive
framing .....: not braced

1.2 main joint data

beam : IPE 240, S 275
column : HEB 240, S 275
flush end plate : 264 X 160 X 15, S 275

1.3 mechanical characteristics

	yield strength N/mm²	ultimate strength N/mm²
beam web	275.00	430.00
beam flange	275.00	430.00
column web	275.00	430.00
column flange	275.00	430.00
end plate	275.00	430.00
bolts in tension	900.00	1000.00

1.4 geometrical characteristics

1.4.1 beam : IPE 240, S 275

depth	240.00 mm
width	120.00 mm
thickness of the flange	9.80 mm
thickness of the web	6.20 mm
root radius	15.00 mm
inertia	3891.63 cm4
area	39.12 cm²
length of the beam connected to the column	6000.00 mm
beam inclination	0.00 °

1.4.2 column : HEB 240, S 275

depth	240.00 mm
width	240.00 mm
thickness of the flange	17.00 mm
thickness of the web	10.00 mm
root radius	21.00 mm
inertia	11259.30 cm4
area	105.99 cm²

1.4.3 end plate 264 X 160 X 15, S 275

vertical distance between the beam flange and the edge of the end plate	12.00 mm
vertical distance between the first bolt row and the edge of the end plate	54.00 mm
horizontal distance between the bolts	96.00 mm
horizontal distance between the bolts and the edge of the end plate	32.00 mm

1.4.4 bolts in tension 10.9

```
resistant area ..........................................:      245.00 mm²
diameter of the shank ...................................:       20.00 mm
diameter of the holes ...................................:       22.00 mm
thickness of the bolt head ..............................:       13.00 mm
thickness of the nut ....................................:       16.00 mm
total thickness of the washer(s) per bolt ...............:        4.00 mm
diameter of the washers .................................:       37.00 mm
```

1.4.5 welds

```
thickness of the weld connecting the beam flange ........:        8.00 mm
thickness of the weld connecting the beam web ...........:        8.00 mm
```

1.5 safety factors

```
gamma M0 ................................................:        1.00
gamma M1 ................................................:        1.00
gamma Mb ................................................:        1.00
gamma Mw ................................................:        1.00
```

2. JOINT PROPERTIES FOR POSITIVE MOMENTS

2.1 CALCULATION OF THE COMPONENTS

2.1.1 column web panel in shear

```
sheared area of the column ..................: Avc    =       33.23 cm²
beta coefficient ..................... ( J.2.6.3 ) : BETA   =        1.00
plastic resistance of the column web panel .....: VwpRd  =      474.77 kN
   ( J.3.5.1)
resistance : vwprd / beta ......................: FwpRd  =      474.77 kN

stiffness coefficient ............. ( Form. J.39 ) : k1     =        6.54 mm
```

2.1.2 column web in compression

```
effective width ................... ( Form. J.20 ) : l1     =      252.43 mm
                                                    l2     =      238.11 mm
                                                 => beff   =      238.11 mm

coefficient for stress interaction .. ( Table J.5 ) : RHO    =        0.77
longitudinal compressive stress in the web adjacent
   to the root radius ..........................: Sigma  =        0.00 N/mm²
reduction factor .................. ( Form. J.22 ) : kwc    =        1.00

strength : ( Form. J.17 )
   * buckling of the web :
     slenderness ...............................: LAMBDA =        0.67
     strength ..................................: Fc2    =      507.06 kN

strength ...........................................: FcwcRd =      507.06 kN
```

```
stiffness coefficient ..... ( Form. J.40 ) : k2     =       10.16 mm
```

2.1.3 column flange in bending

```
geometrical parameters ..... ( Fig. J.25 ) : e      =       72.00 mm
======================                       emin   =       32.00 mm
                                             m      =       26.20 mm
                                             n      =       32.00 mm
                                             ew     =        9.25 mm
```

2.1.3.1 effective length of the equivalent t-stub (Tables J.6 - J.7)

```
   * circular patterns :
        2 Pi m ..................................: l      =      164.62 mm
   * other patterns :
        4 m + 1.25 e ............................: l      =      194.80 mm

   for all bolt rows :
   * circular patterns .........................: leff   =      164.62 mm
   * other patterns ............................: leff   =      194.80 mm
```

2.1.3.2 strength

```
( J.3.5.4.2 )
design resistance of a bolt ....... ( Table 6.5.3 ) : BtRd   =      220.50 kN

*  bolt row nb 1

   longitudinal compressive stress in the flange ...: Sigma  =        0.00 N/mm²
   reduction factor ................ ( Form. J.29 ) : kfc    =        1.00

   mode of collapse for equivalent T-stub ( J.3.2.1 )

   design plastic resistance of the T-stub ( Form. J.7 )
      for complete yielding of the flange ..........: Mpl1Rd =     3270.78 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =     3870.43 Nm

   mode 1 : complete yielding of the flange ........: F1Rd   =      499.36 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      375.48 kN
   mode 3 : bolts failure ..........................: F3Rd   =      441.00 kN
            ( Form. J.4 - J.5 - J.6 )

   strength ....................................: FtRd(1)  =      375.48 kN
```

2.1.3.3 stiffness

```
*  effective length of the equivalent t-stub
   bolt rows are considered individually or as part of a group

   bolt row nb  1 ..............................: beff(1)  =      164.62 mm

*  stiffness coefficient ( Form. J.42 )

   bolt row nb  1 ..............................: k3(1)    =       38.22 mm
```

2.1.4 column web in tension

2.1.4.1 strength

bolt row nb	coefficient for stress interaction (Table J.5)	strength (kN)
1	0.83	445.36

2.1.4.2 stiffness

bolt row nb 1 .....: k4(1) = 7.03 mm

2.1.5 end plate in bending

geometrical parameters ..... (Fig. J.28) : e = 72.00 mm
========== m = 35.85 mm

bolt row nb 1 (below the top beam flange) .....: m1 = 35.85 mm
m2 = 23.15 mm
determination of the alpha coefficient .....: Lambda1= 0.53
(Fig. J.27) Lambda2= 0.34
ALPHA = 5.98

bolt row nb 1 (up to the bottom beam flange) ..: m1 = 35.85 mm
m2 = 179.15 mm
determination of the alpha coefficient .....: Lambda1= 0.53
(Fig. J.27) Lambda2= 2.64
ALPHA = 5.13

2.1.5.1 effective length of the equivalent t-stub (Tables J.8) :

bolt row nb 1 (influence of the upper beam flange)
* circular patterns :
2 Pi m1 .....: leff = 225.25 mm
* other patterns :
Alpha m1 .....: leff = 214.48 mm

bolt row nb 2 (not influenced by the beam flanges)
* circular patterns :
2 Pi m1 .....: leff = 0.00 mm
* other patterns :
4 m1 + 1.25 e .....: leff = 0.00 mm

bolt row nb 1 (influence of the lower beam flange)
* circular patterns :
2 Pi m1 .....: leff = 225.25 mm
* other patterns :
Alpha m1 .....: leff = 214.48 mm

2.1.5.2 strength

* bolt row nb 1

mode of collapse for equivalent T-stub (J.3.2.1)

design plastic resistance of the T-stub (Form. J.7)

```
      for complete yielding of the flange ..........: Mpl1Rd =     3317.68 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =     3317.68 Nm

   mode 1 : complete yielding of the flange ........: F1Rd   =      370.18 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      305.79 kN
   mode 3 : bolts failure ..........................: F3Rd   =      441.00 kN
            ( Form. J.4 - J.5 - J.6 )

   strength ....................................: FtepRd(1)=      305.79 kN
```

2.1.5.3 stiffness

```
*  effective length of the equivalent t-stub
   bolt rows are considered individually or as part of a group

   bolt row nb  1 ..............................: leff(1) =      112.62 mm

*  stiffness coefficient ( Form. J.43 )

   bolt row nb  1 ..............................: k5(1)  =        7.01 mm
```

2.1.5.4 bolts in tension

```
length of the bolt .................. ( J.4.4.10 ) : Lb     =       50.50 mm
strength ........................... ( Table 6.5.3 ) : BtRd   =      220.50 kN
stiffness coefficient .............. ( Form. J.45 ) : k7     =        7.76 mm
```

2.1.6 beam flange in compression

```
moment resistance of the beam cross-section ........: McRd   =      100.83 kNm
strength ........................... ( Form. J.30 ) : FcfbRd =      438.00 kN
```

2.1.7 beam web in tension

```
effective width
   => equal to the ones of the end plate in bending
```

2.1.7.1 strength

bolt row nb		strength (kN) (Form. J.31) FtwbRd(i)
1	:	365.68

2.2 ASSEMBLY OF THE COMPONENTS

2.2.1 strength (Fig. J.34)

2.2.1.1 bolt row nb 1

```
                                                              strength (kN)

   column web panel in shear ..................................:     474.77
```

```
   column web in compression ..................................:      507.06
   column flange in bending ...................................:      375.48
   column web in tension ......................................:      445.36
   end plate in bending .......................................:      305.79
   bolts in tension ...........................................:      441.00
   beam flange in compression .................................:      438.00
   beam web in tension ........................................:      365.68
                                                                    ---------
   resistance of bolt row nb  1 ....................: Frd(1) =      305.79 kN


plastic distribution of the internal forces
```

2.2.1.2 summary

```
   resistance of bolt row nb  1 ....................: FRd(1) =      305.79 kN

   moment resistance (weld failure disregarded) .....: MRdj   =       59.05 kNm
   moment resistance of the welds ...................: MRdw   =      129.09 kNm
                                                                    ---------
   moment resistance ..................... ( J.3.6 ) :                59.05 kNm

   elastic moment resistance ............. ( J.2.1.2 ) : Me     =       39.37 kNm
```

2.2.2 stiffness

2.2.2.1 determination of the equivalent stiffness coefficient

```
                        effective stiffness
                        coefficient (mm)          lever arm of internal forces
                        ( Form. J.36 )

   bolt row nb  1 : keff,1 =       2.27               h 1 =      193.10

   lever arm of internal forces ..... ( Form. J.38 ) : z      =      193.10 mm
   equivalent stiffness coefficient ... ( Form. J.36 ) : keq    =        2.27 mm
```

2.2.2.2 percentages of flexibility

```
   the flexibility of each bolt row is the relative flexibility of each
   bolt row in comparison with the other ones regardless of the lever arms

   for the sheared panel                22 %
   for the compression zone             14 %
   for the tension zone                 64 %
      * bolt row nb 1                          ** %
           end plate in bending                                  32 %
           bolts in tension                                      29 %
```

2.2.2.3 summary

```
   initial stiffness .................. ( Form. J.34 ) : Sji    =    11328.06 kNm/rad
   idealized stiffness . ( J.2.1.2 - J.2.1.4 - T.J.3 ) : Sjn    =     5664.03 kNm/rad
   secant stiffness ................... ( Form. J.34 ) : Sjs    =     3790.61 kNm/rad
```

2.2.3 shear resistance

```
shear resistance of one bolt row .. ( Table 6.5.3 ) : FvRd   =      245.00 kN


column flange in bearing ( Table 6.5.3 ):
                                          p1/(3d0)-0.25 =      151.27
                                          fub / fu      =        2.33
                                          =>     ALPHA  =        1.00
   bearing resistance of one bolt row ..............: FbRd   =      731.00 kN

end plate in bearing :
                                          p1/(3d0)-0.25 =      151.27
                                          fub / fu      =        2.33
                                          =>     ALPHA  =        1.00
   bearing resistance of one bolt row ..............: FbRd   =      612.16 kN

the shear resistance of a bolt row submited to both
   shear and tensile forces is reduced by a factor 0.4/1.4
               ( J.3.1.2.(2b) )

shear resistance of the bolt row n°  1 ..........: Vrd(1) =       70.00 kN

shear resistance of the welds
   correlation factor ............. ( 6.6.5.3.(5) ) : BETA   =        0.85
   length of the weld ..............................: a      =      190.40 mm
   shear resistance of the welds .. ( 6.6.5.3.(4) ) : FwRd   =      889.77 kN

design shear resistance of the joint ..............: VRd    =       70.00 kN
```

2.2.4 collapse mode

```
bolt row nb 1 : end plate in bending

not enough rotation capacity for plastic global analysis
```

2.3 DESIGN PROPERTIES OF THE JOINT FOR PLASTIC ANALYSIS / PLASTIC JOINT DESIGN

```
design moment resistance ............................: MRd    =       59.05 kNm

initial stiffness ................. ( Form. J.34 ) : Sji    =    11328.06 kNm/rad
idealized stiffness . ( J.2.1.2 - J.2.1.4 - T.J.3 ) : Sjn    =     5664.03 kNm/rad
```

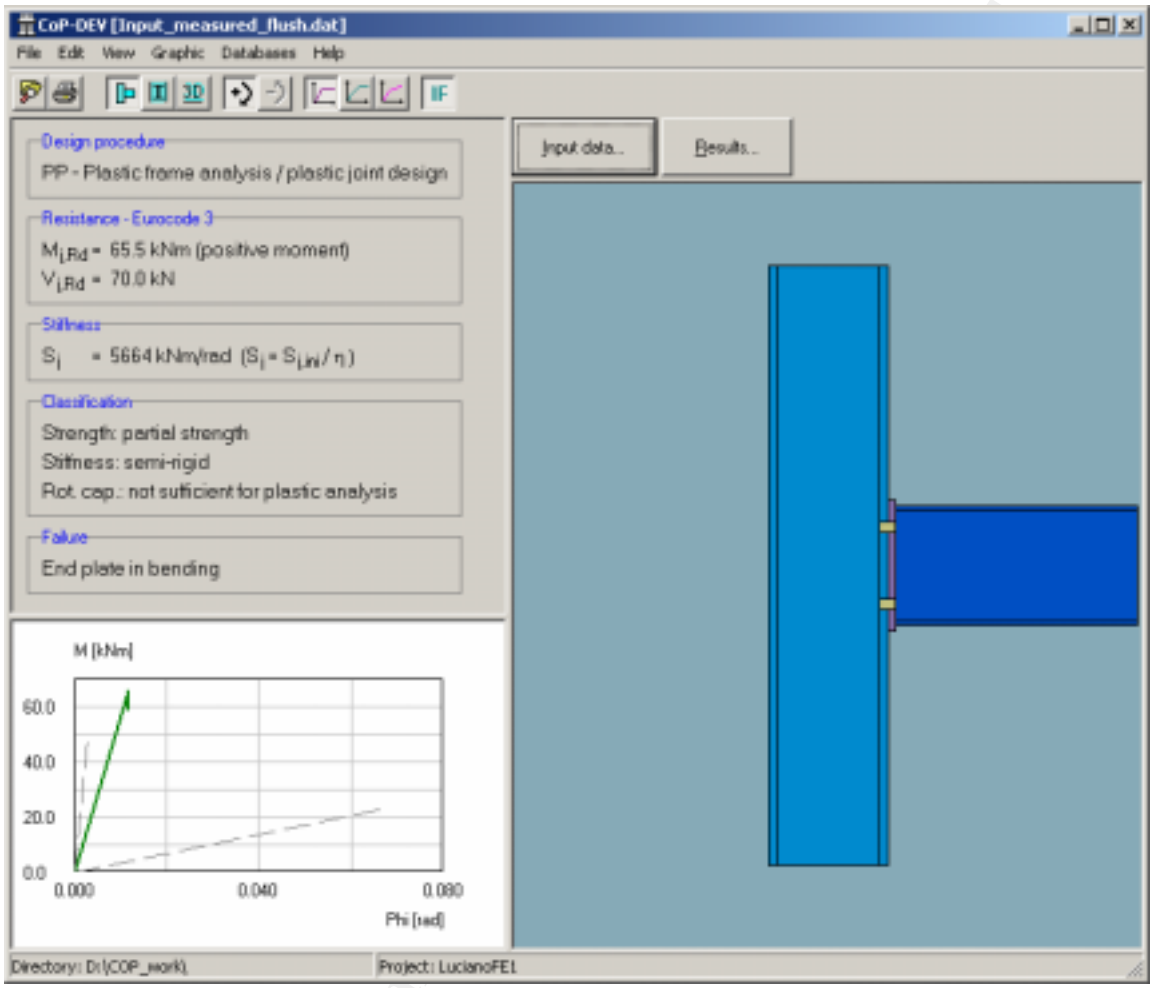
3. References

[1] ENV 1993-1-1 : 1992, Eurocode 3: Design of steel structures.
Part 1.1: General rules and rules for buildings,
CEN, Brussels 1992.

[2] ENV 1993-1-1 : 1992/A2, October 1998.
Revised Annex J of Eurocode 3, "Joints in Building Frames",
CEN, Brussels, October 1998.

FE1, measured properties, no safety factors

Design of joints in building frames
according to Eurocode 3 - revised Annex J



1. INPUT DATA

1.1 PROJECT DATA

```
project .....................: MSc in Civil Engineering - Structures
structure ...................: FE1
joint .......................: Flush End Plate Tested by Luciano Lima in Coimbra
joint id ....................: FE1 - measured
engineer ....................: LB
date ........................: 28-03-2003

design procedure ............: plastic analysis / plastic joint design
```

environment .....: not corrosive
framing .....: not braced

1.2 main joint data

beam : IPE 240, S 275
column : HEB 240, S 275
flush end plate : 264 X 160 X 15, S 275

1.3 mechanical characteristics

	yield strength N/mm²	ultimate strength N/mm²
beam web	363.40	430.00
beam flange	340.10	430.00
column web	372.00	430.00
column flange	342.90	430.00
end plate	369.40	430.00
bolts in tension	900.00	1000.00

1.4 geometrical characteristics

1.4.1 beam : IPE 240, S 275

depth	240.00 mm
width	120.00 mm
thickness of the flange	9.80 mm
thickness of the web	6.20 mm
root radius	15.00 mm
inertia	3891.63 cm4
area	39.12 cm²
length of the beam connected to the column	6000.00 mm
beam inclination	0.00 °

1.4.2 column : HEB 240, S 275

depth	240.00 mm
width	240.00 mm
thickness of the flange	17.00 mm
thickness of the web	10.00 mm
root radius	21.00 mm
inertia	11259.30 cm4
area	105.99 cm²

1.4.3 end plate 264 X 160 X 15, S 275

vertical distance between the beam flange and the edge of the end plate	12.00 mm
vertical distance between the first bolt row and the edge of the end plate	54.00 mm
horizontal distance between the bolts	96.00 mm
horizontal distance between the bolts and the edge of the end plate	32.00 mm

1.4.4 bolts in tension 10.9

```
resistant area ..........................................:      245.00 mm²
diameter of the shank ...................................:       20.00 mm
diameter of the holes ...................................:       22.00 mm
thickness of the bolt head ..............................:       13.00 mm
thickness of the nut ....................................:       16.00 mm
total thickness of the washer(s) per bolt ...............:        4.00 mm
diameter of the washers .................................:       37.00 mm
```

1.4.5 welds

```
thickness of the weld connecting the beam flange ........:        8.00 mm
thickness of the weld connecting the beam web ...........:        8.00 mm
```

1.5 safety factors

```
gamma M0 ................................................:        1.00
gamma M1 ................................................:        1.00
gamma Mb ................................................:        1.00
gamma Mw ................................................:        1.00
```

2. JOINT PROPERTIES FOR POSITIVE MOMENTS

2.1 CALCULATION OF THE COMPONENTS

2.1.1 column web panel in shear

```
sheared area of the column ..................: Avc    =       33.23 cm²
beta coefficient ..................... ( J.2.6.3 ) : BETA   =        1.00
plastic resistance of the column web panel .....: VwpRd  =      642.24 kN
   ( J.3.5.1)
resistance : vwprd / beta ......................: FwpRd  =      642.24 kN

stiffness coefficient ............. ( Form. J.39 ) : k1     =        6.54 mm
```

2.1.2 column web in compression

```
effective width ................... ( Form. J.20 ) : l1     =      252.43 mm
                                                    l2     =      238.11 mm
                                                 => beff   =      238.11 mm

coefficient for stress interaction .. ( Table J.5 ) : RHO    =        0.77
longitudinal compressive stress in the web adjacent
   to the root radius ..........................: Sigma  =        0.00 N/mm²
reduction factor .................. ( Form. J.22 ) : kwc    =        1.00

strength : ( Form. J.17 )
   * buckling of the web :
     slenderness ...............................: LAMBDA =        0.77
     strength ..................................: Fc2    =      685.92 kN

strength ...................................: FcwcRd =      634.55 kN
```

```
stiffness coefficient ..... ( Form. J.40 ) : k2     =       10.16 mm
```

2.1.3 column flange in bending

```
geometrical parameters ..... ( Fig. J.25 ) : e      =       72.00 mm
======================                       emin   =       32.00 mm
                                             m      =       26.20 mm
                                             n      =       32.00 mm
                                             ew     =        9.25 mm
```

2.1.3.1 effective length of the equivalent t-stub (Tables J.6 - J.7)

```
   * circular patterns :
        2 Pi m ..................................: l      =      164.62 mm
   * other patterns :
        4 m + 1.25 e ............................: l      =      194.80 mm

   for all bolt rows :
   * circular patterns .........................: leff   =      164.62 mm
   * other patterns ............................: leff   =      194.80 mm
```

2.1.3.2 strength

```
( J.3.5.4.2 )
design resistance of a bolt ....... ( Table 6.5.3 ) : BtRd   =      220.50 kN

*  bolt row nb 1

   longitudinal compressive stress in the flange ...: Sigma  =        0.00 N/mm²
   reduction factor ................ ( Form. J.29 ) : kfc    =        1.00

   mode of collapse for equivalent T-stub ( J.3.2.1 )

   design plastic resistance of the T-stub ( Form. J.7 )
      for complete yielding of the flange ..........: Mpl1Rd =     4078.37 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =     4826.08 Nm

   mode 1 : complete yielding of the flange ........: F1Rd   =      622.65 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      408.32 kN
   mode 3 : bolts failure ..........................: F3Rd   =      441.00 kN
            ( Form. J.4 - J.5 - J.6 )

   strength ....................................: FtRd(1)  =      408.32 kN
```

2.1.3.3 stiffness

```
*  effective length of the equivalent t-stub
   bolt rows are considered individually or as part of a group

   bolt row nb  1 ..............................: beff(1)  =      164.62 mm

*  stiffness coefficient ( Form. J.42 )

   bolt row nb  1 ..............................: k3(1)    =       38.22 mm
```

2.1.4 column web in tension

2.1.4.1 strength

bolt row nb	coefficient for stress interaction (Table J.5)	strength (kN)
1	0.83	602.45

2.1.4.2 stiffness

bolt row nb 1 .....: k4(1) = 7.03 mm

2.1.5 end plate in bending

geometrical parameters ..... (Fig. J.28) : e = 72.00 mm
========== m = 35.85 mm

bolt row nb 1 (below the top beam flange) .....: m1 = 35.85 mm
m2 = 23.15 mm
determination of the alpha coefficient .....: Lambda1= 0.53
(Fig. J.27) Lambda2= 0.34
ALPHA = 5.98

bolt row nb 1 (up to the bottom beam flange) ..: m1 = 35.85 mm
m2 = 179.15 mm
determination of the alpha coefficient .....: Lambda1= 0.53
(Fig. J.27) Lambda2= 2.64
ALPHA = 5.13

2.1.5.1 effective length of the equivalent t-stub (Tables J.8) :

bolt row nb 1 (influence of the upper beam flange)
* circular patterns :
2 Pi m1 .....: leff = 225.25 mm
* other patterns :
Alpha m1 .....: leff = 214.48 mm

bolt row nb 2 (not influenced by the beam flanges)
* circular patterns :
2 Pi m1 .....: leff = 0.00 mm
* other patterns :
4 m1 + 1.25 e .....: leff = 0.00 mm

bolt row nb 1 (influence of the lower beam flange)
* circular patterns :
2 Pi m1 .....: leff = 225.25 mm
* other patterns :
Alpha m1 .....: leff = 214.48 mm

2.1.5.2 strength

* bolt row nb 1

mode of collapse for equivalent T-stub (J.3.2.1)

design plastic resistance of the T-stub (Form. J.7)

```
      for complete yielding of the flange ..........: Mpl1Rd =     4456.55 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =     4456.55 Nm

   mode 1 : complete yielding of the flange ........: F1Rd   =      497.26 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      339.36 kN
   mode 3 : bolts failure ..........................: F3Rd   =      441.00 kN
            ( Form. J.4 - J.5 - J.6 )

   strength ....................................: FtepRd(1)=      339.36 kN
```

2.1.5.3 stiffness

```
*  effective length of the equivalent t-stub
   bolt rows are considered individually or as part of a group

   bolt row nb  1 ..............................: leff(1) =      112.62 mm

*  stiffness coefficient ( Form. J.43 )

   bolt row nb  1 ..............................: k5(1)  =        7.01 mm
```

2.1.5.4 bolts in tension

```
length of the bolt .................. ( J.4.4.10 ) : Lb     =       50.50 mm
strength ........................... ( Table 6.5.3 ) : BtRd   =      220.50 kN
stiffness coefficient .............. ( Form. J.45 ) : k7     =        7.76 mm
```

2.1.6 beam flange in compression

```
moment resistance of the beam cross-section ........: McRd   =      127.89 kNm
strength ........................... ( Form. J.30 ) : FcfbRd =      555.57 kN
```

2.1.7 beam web in tension

```
effective width
   => equal to the ones of the end plate in bending
```

2.1.7.1 strength

bolt row nb		strength (kN) (Form. J.31) FtwbRd(i)
1	:	483.23

2.2 ASSEMBLY OF THE COMPONENTS

2.2.1 strength (Fig. J.34)

2.2.1.1 bolt row nb 1

```
                                                              strength (kN)

   column web panel in shear ..................................:      642.24
```

```
   column web in compression ..................................:      634.55
   column flange in bending ...................................:      408.32
   column web in tension ......................................:      602.45
   end plate in bending .......................................:      339.36
   bolts in tension ...........................................:      441.00
   beam flange in compression .................................:      555.57
   beam web in tension ........................................:      483.23
                                                                    ---------
   resistance of bolt row nb  1 ....................: Frd(1) =      339.36 kN


plastic distribution of the internal forces
```

2.2.1.2 summary

```
   resistance of bolt row nb  1 ....................: FRd(1) =      339.36 kN

   moment resistance (weld failure disregarded) .....: MRdj   =       65.53 kNm
   moment resistance of the welds ...................: MRdw   =      129.09 kNm
                                                                    ---------
   moment resistance ..................... ( J.3.6 ) :                65.53 kNm

   elastic moment resistance ............. ( J.2.1.2 ) : Me     =       43.69 kNm
```

2.2.2 stiffness

2.2.2.1 determination of the equivalent stiffness coefficient

```
                        effective stiffness
                        coefficient (mm)          lever arm of internal forces
                        ( Form. J.36 )

   bolt row nb  1 : keff,1 =       2.27               h 1 =      193.10

   lever arm of internal forces ..... ( Form. J.38 ) : z      =      193.10 mm
   equivalent stiffness coefficient ... ( Form. J.36 ) : keq    =        2.27 mm
```

2.2.2.2 percentages of flexibility

```
   the flexibility of each bolt row is the relative flexibility of each
   bolt row in comparison with the other ones regardless of the lever arms

   for the sheared panel                22 %
   for the compression zone             14 %
   for the tension zone                 64 %
      * bolt row nb 1                          ** %
           end plate in bending                                  32 %
           bolts in tension                                      29 %
```

2.2.2.3 summary

```
   initial stiffness .................. ( Form. J.34 ) : Sji    =    11328.06 kNm/rad
   idealized stiffness . ( J.2.1.2 - J.2.1.4 - T.J.3 ) : Sjn    =     5664.03 kNm/rad
   secant stiffness ................... ( Form. J.34 ) : Sjs    =     3790.61 kNm/rad
```

2.2.3 shear resistance

```
shear resistance of one bolt row .. ( Table 6.5.3 ) : FvRd   =      245.00 kN


column flange in bearing ( Table 6.5.3 ):
                                          p1/(3d0)-0.25 =      151.27
                                          fub / fu      =        2.33
                                          =>     ALPHA  =        1.00
   bearing resistance of one bolt row ..............: FbRd   =      731.00 kN

end plate in bearing :
                                          p1/(3d0)-0.25 =      151.27
                                          fub / fu      =        2.33
                                          =>     ALPHA  =        1.00
   bearing resistance of one bolt row ..............: FbRd   =      612.16 kN

the shear resistance of a bolt row submited to both
   shear and tensile forces is reduced by a factor 0.4/1.4
               ( J.3.1.2.(2b) )

shear resistance of the bolt row n°  1 .........: Vrd(1) =       70.00 kN

shear resistance of the welds
   correlation factor ............. ( 6.6.5.3.(5) ) : BETA   =        0.85
   length of the weld ..............................: a      =      190.40 mm
   shear resistance of the welds .. ( 6.6.5.3.(4) ) : FwRd   =      889.77 kN

design shear resistance of the joint ..............: VRd    =       70.00 kN
```

2.2.4 collapse mode

```
bolt row nb 1 : end plate in bending

not enough rotation capacity for plastic global analysis
```

2.3 DESIGN PROPERTIES OF THE JOINT FOR PLASTIC ANALYSIS / PLASTIC JOINT DESIGN

```
design moment resistance ............................: MRd    =       65.53 kNm

initial stiffness .................. ( Form. J.34 ) : Sji    =    11328.06 kNm/rad
idealized stiffness . ( J.2.1.2 - J.2.1.4 - T.J.3 ) : Sjn    =     5664.03 kNm/rad
```

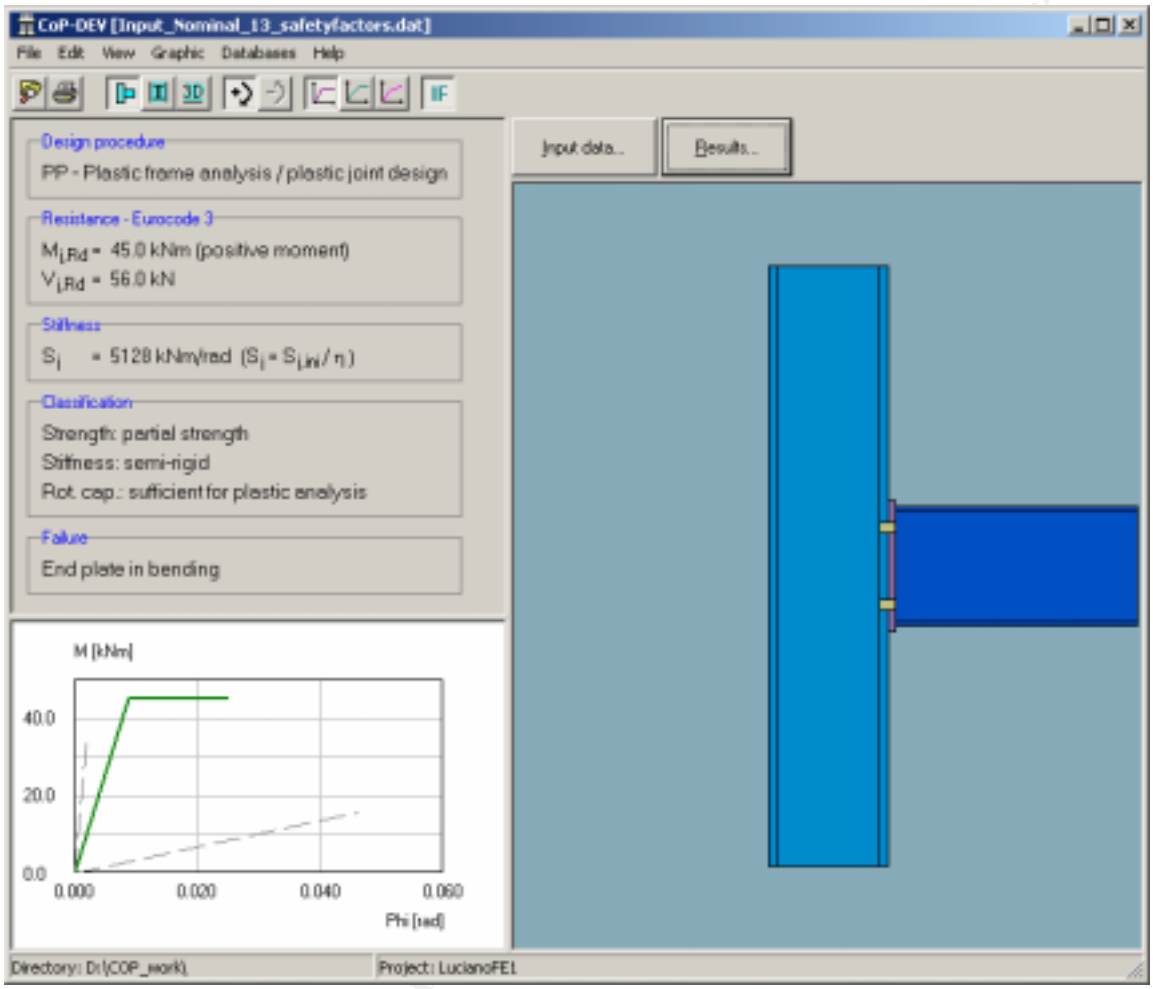
3. References

[1] ENV 1993-1-1 : 1992, Eurocode 3: Design of steel structures.
Part 1.1: General rules and rules for buildings,
CEN, Brussels 1992.

[2] ENV 1993-1-1 : 1992/A2, October 1998.
Revised Annex J of Eurocode 3, "Joints in Building Frames",
CEN, Brussels, October 1998.

FE1 modified endplate=13 mm, nominal properties, safety factors,

Design of joints in building frames
according to Eurocode 3 - revised Annex J



1. INPUT DATA

1.1 PROJECT DATA

```
project .....................: MSc in Civil Engineering - Structures
structure ...................: FE1
joint .......................: Flush End Plate Tested by Luciano Lima in Coimbra
joint id ....................: FE1 - Nominal + safety factors 13
engineer ....................: LB
date ........................: 28-03-2003

design procedure ............: plastic analysis / plastic joint design
```

environment .....: not corrosive
framing .....: not braced

1.2 main joint data

beam : IPE 240, S 275
column : HEB 240, S 275
flush end plate : 264 X 160 X 13, S 275

1.3 mechanical characteristics

	yield strength N/mm²	ultimate strength N/mm²
beam web .....:	275.00	430.00
beam flange .....:	275.00	430.00
column web .....:	275.00	430.00
column flange .....:	275.00	430.00
end plate .....:	275.00	430.00
bolts in tension .....:	900.00	1000.00

1.4 geometrical characteristics

1.4.1 beam : IPE 240, S 275

depth .....:	240.00 mm
width .....:	120.00 mm
thickness of the flange .....:	9.80 mm
thickness of the web .....:	6.20 mm
root radius .....:	15.00 mm
inertia .....:	3891.63 cm4
area .....:	39.12 cm²
length of the beam connected to the column .....:	6000.00 mm
beam inclination .....:	0.00 °

1.4.2 column : HEB 240, S 275

depth .....:	240.00 mm
width .....:	240.00 mm
thickness of the flange .....:	17.00 mm
thickness of the web .....:	10.00 mm
root radius .....:	21.00 mm
inertia .....:	11259.30 cm4
area .....:	105.99 cm²

1.4.3 end plate 264 X 160 X 13, S 275

vertical distance between the beam flange and the edge of the end plate .....:	12.00 mm
vertical distance between the first bolt row and the edge of the end plate .....:	54.00 mm
horizontal distance between the bolts .....:	96.00 mm
horizontal distance between the bolts and the edge of the end plate .....:	32.00 mm

1.4.4 bolts in tension 10.9

```
resistant area ..........................................:      245.00 mm²
diameter of the shank ...................................:       20.00 mm
diameter of the holes ...................................:       22.00 mm
thickness of the bolt head ..............................:       13.00 mm
thickness of the nut ....................................:       16.00 mm
total thickness of the washer(s) per bolt ...............:        4.00 mm
diameter of the washers .................................:       37.00 mm
```

1.4.5 welds

```
thickness of the weld connecting the beam flange ........:        8.00 mm
thickness of the weld connecting the beam web ...........:        8.00 mm
```

1.5 safety factors

```
gamma M0 ................................................:        1.10
gamma M1 ................................................:        1.10
gamma Mb ................................................:        1.25
gamma Mw ................................................:        1.25
```

2. JOINT PROPERTIES FOR POSITIVE MOMENTS

2.1 CALCULATION OF THE COMPONENTS

2.1.1 column web panel in shear

```
sheared area of the column ..................: Avc    =       33.23 cm²
beta coefficient ..................... ( J.2.6.3 ) : BETA   =        1.00
plastic resistance of the column web panel .....: VwpRd  =      431.61 kN
   ( J.3.5.1)
resistance : vwprd / beta ......................: FwpRd  =      431.61 kN

stiffness coefficient ............. ( Form. J.39 ) : k1     =        6.54 mm
```

2.1.2 column web in compression

```
effective width ................... ( Form. J.20 ) : l1     =      248.43 mm
                                                    l2     =      236.11 mm
                                                 => beff   =      236.11 mm

coefficient for stress interaction .. ( Table J.5 ) : RHO    =        0.78
longitudinal compressive stress in the web adjacent
   to the root radius ..........................: Sigma  =        0.00 N/mm²
reduction factor .................. ( Form. J.22 ) : kwc    =        1.00

strength : ( Form. J.17 )
   * buckling of the web :
     slenderness ...............................: LAMBDA =        0.66
     strength ..................................: Fc2    =      458.63 kN

strength ...........................................: FcwcRd =      458.63 kN
```

```
stiffness coefficient ..... ( Form. J.40 ) : k2     =       10.08 mm
```

2.1.3 column flange in bending

```
geometrical parameters ..... ( Fig. J.25 ) : e      =       72.00 mm
======================                       emin   =       32.00 mm
                                             m      =       26.20 mm
                                             n      =       32.00 mm
                                             ew     =        9.25 mm
```

2.1.3.1 effective length of the equivalent t-stub (Tables J.6 - J.7)

```
   * circular patterns :
        2 Pi m ..................................: l      =      164.62 mm
   * other patterns :
        4 m + 1.25 e ............................: l      =      194.80 mm

   for all bolt rows :
   * circular patterns .........................: leff   =      164.62 mm
   * other patterns ............................: leff   =      194.80 mm
```

2.1.3.2 strength

```
( J.3.5.4.2 )
design resistance of a bolt ....... ( Table 6.5.3 ) : BtRd   =      176.40 kN

*  bolt row nb 1

   longitudinal compressive stress in the flange ...: Sigma  =        0.00 N/mm²
   reduction factor ................ ( Form. J.29 ) : kfc    =        1.00

   mode of collapse for equivalent T-stub ( J.3.2.1 )

   design plastic resistance of the T-stub ( Form. J.7 )
      for complete yielding of the flange ..........: Mpl1Rd =     2973.44 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =     3518.57 Nm

   mode 1 : complete yielding of the flange ........: F1Rd   =      453.96 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      314.89 kN
   mode 3 : bolts failure ..........................: F3Rd   =      352.80 kN
            ( Form. J.4 - J.5 - J.6 )

   strength ....................................: FtRd(1)  =      314.89 kN
```

2.1.3.3 stiffness

```
*  effective length of the equivalent t-stub
   bolt rows are considered individually or as part of a group

   bolt row nb  1 ..............................: beff(1)  =      164.62 mm

*  stiffness coefficient ( Form. J.42 )

   bolt row nb  1 ..............................: k3(1)    =       38.22 mm
```

2.1.4 column web in tension

2.1.4.1 strength

bolt row nb	coefficient for stress interaction (Table J.5)	strength (kN)
1	0.83	404.87

2.1.4.2 stiffness

bolt row nb 1 .....: k4(1) = 7.03 mm

2.1.5 end plate in bending

geometrical parameters ..... (Fig. J.28) : e = 72.00 mm
==========
m = 35.85 mm

bolt row nb 1 (below the top beam flange) .....: m1 = 35.85 mm
m2 = 23.15 mm
determination of the alpha coefficient .....: Lambda1= 0.53
(Fig. J.27) Lambda2= 0.34
ALPHA = 5.98

bolt row nb 1 (up to the bottom beam flange) ..: m1 = 35.85 mm
m2 = 179.15 mm
determination of the alpha coefficient .....: Lambda1= 0.53
(Fig. J.27) Lambda2= 2.64
ALPHA = 5.13

2.1.5.1 effective length of the equivalent t-stub (Tables J.8) :

bolt row nb 1 (influence of the upper beam flange)
* circular patterns :
2 Pi m1 .....: leff = 225.25 mm
* other patterns :
Alpha m1 .....: leff = 214.48 mm

bolt row nb 2 (not influenced by the beam flanges)
* circular patterns :
2 Pi m1 .....: leff = 0.00 mm
* other patterns :
4 m1 + 1.25 e .....: leff = 0.00 mm

bolt row nb 1 (influence of the lower beam flange)
* circular patterns :
2 Pi m1 .....: leff = 225.25 mm
* other patterns :
Alpha m1 .....: leff = 214.48 mm

2.1.5.2 strength

* bolt row nb 1

mode of collapse for equivalent T-stub (J.3.2.1)

design plastic resistance of the T-stub (Form. J.7)

```
      for complete yielding of the flange .....: Mpl1Rd =     2265.41 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =     2265.41 Nm

   mode 1 : complete yielding of the flange .....: F1Rd   =      252.77 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      233.17 kN
   mode 3 : bolts failure .....................: F3Rd   =      352.80 kN
            ( Form. J.4 - J.5 - J.6 )

   strength ..................................: FtepRd(1)=      233.17 kN
```

2.1.5.3 stiffness

```
*  effective length of the equivalent t-stub
   bolt rows are considered individually or as part of a group

   bolt row nb  1 ............................: leff(1) =      112.62 mm

*  stiffness coefficient ( Form. J.43 )

   bolt row nb  1 ............................: k5(1)  =        4.57 mm
```

2.1.5.4 bolts in tension

```
length of the bolt ................. ( J.4.4.10 ) : Lb     =       48.50 mm
strength ........................... ( Table 6.5.3 ) : BtRd   =      176.40 kN
stiffness coefficient .............. ( Form. J.45 ) : k7     =        8.08 mm
```

2.1.6 beam flange in compression

```
moment resistance of the beam cross-section .....: McRd   =       91.66 kNm
strength ........................ ( Form. J.30 ) : FcfbRd =      398.18 kN
```

2.1.7 beam web in tension

```
effective width
   => equal to the ones of the end plate in bending
```

2.1.7.1 strength

bolt row nb	strength (kN) (Form. J.31) FtwbRd(i)
1 :	332.44

2.2 ASSEMBLY OF THE COMPONENTS

2.2.1 strength (Fig. J.34)

2.2.1.1 bolt row nb 1

```
                                                          strength (kN)

column web panel in shear ..............................:      431.61
```

```
   column web in compression ..................................:      458.63
   column flange in bending ...................................:      314.89
   column web in tension ......................................:      404.87
   end plate in bending .......................................:      233.17
   bolts in tension ...........................................:      352.80
   beam flange in compression .................................:      398.18
   beam web in tension ........................................:      332.44
                                                                    ---------
   resistance of bolt row nb  1 ....................: Frd(1) =      233.17 kN


plastic distribution of the internal forces
```

2.2.1.2 summary

```
   resistance of bolt row nb  1 ....................: FRd(1) =      233.17 kN

   moment resistance (weld failure disregarded) .....: MRdj   =       45.03 kNm
   moment resistance of the welds ...................: MRdw   =      103.27 kNm
                                                                    ---------
   moment resistance ..................... ( J.3.6 ) :                45.03 kNm

   elastic moment resistance ............. ( J.2.1.2 ) : Me     =       30.02 kNm
```

2.2.2 stiffness

2.2.2.1 determination of the equivalent stiffness coefficient

```
                        effective stiffness
                        coefficient (mm)          lever arm of internal forces
                        ( Form. J.36 )

   bolt row nb  1 : keff,1 =       1.96               h 1 =      193.10

   lever arm of internal forces ..... ( Form. J.38 ) : z      =      193.10 mm
   equivalent stiffness coefficient ... ( Form. J.36 ) : keq    =        1.96 mm
```

2.2.2.2 percentages of flexibility

```
   the flexibility of each bolt row is the relative flexibility of each
   bolt row in comparison with the other ones regardless of the lever arms

   for the sheared panel                20 %
   for the compression zone             13 %
   for the tension zone                 67 %
      * bolt row nb 1                          ** %
           end plate in bending                                  43 %
           bolts in tension                                      24 %
```

2.2.2.3 summary

```
   initial stiffness .................. ( Form. J.34 ) : Sji    =    10256.87 kNm/rad
   idealized stiffness . ( J.2.1.2 - J.2.1.4 - T.J.3 ) : Sjn    =     5128.44 kNm/rad
   secant stiffness ................... ( Form. J.34 ) : Sjs    =     3432.17 kNm/rad
```

2.2.3 shear resistance

```
shear resistance of one bolt row .. ( Table 6.5.3 ) : FvRd   =      196.00 kN


column flange in bearing ( Table 6.5.3 ):
                                          p1/(3d0)-0.25 =      151.27
                                          fub / fu      =        2.33
                                          =>     ALPHA  =        1.00
   bearing resistance of one bolt row ..............: FbRd   =      584.80 kN

end plate in bearing :
                                          p1/(3d0)-0.25 =      151.27
                                          fub / fu      =        2.33
                                          =>     ALPHA  =        1.00
   bearing resistance of one bolt row ..............: FbRd   =      424.43 kN

the shear resistance of a bolt row submited to both
   shear and tensile forces is reduced by a factor 0.4/1.4
               ( J.3.1.2.(2b) )

shear resistance of the bolt row n°  1 .........: Vrd(1) =       56.00 kN

shear resistance of the welds
   correlation factor ............. ( 6.6.5.3.(5) ) : BETA   =        0.85
   length of the weld ..............................: a      =      190.40 mm
   shear resistance of the welds .. ( 6.6.5.3.(4) ) : FwRd   =      711.81 kN

design shear resistance of the joint ..............: VRd    =       56.00 kN
```

2.2.4 collapse mode

```
bolt row nb 1 : end plate in bending

sufficient rotation capacity for plastic global analysis
```

2.3 DESIGN PROPERTIES OF THE JOINT FOR PLASTIC ANALYSIS / PLASTIC JOINT DESIGN

```
design moment resistance ............................: MRd    =       45.03 kNm

initial stiffness .................. ( Form. J.34 ) : Sji    =    10256.87 kNm/rad
idealized stiffness . ( J.2.1.2 - J.2.1.4 - T.J.3 ) : Sjn    =     5128.44 kNm/rad
```

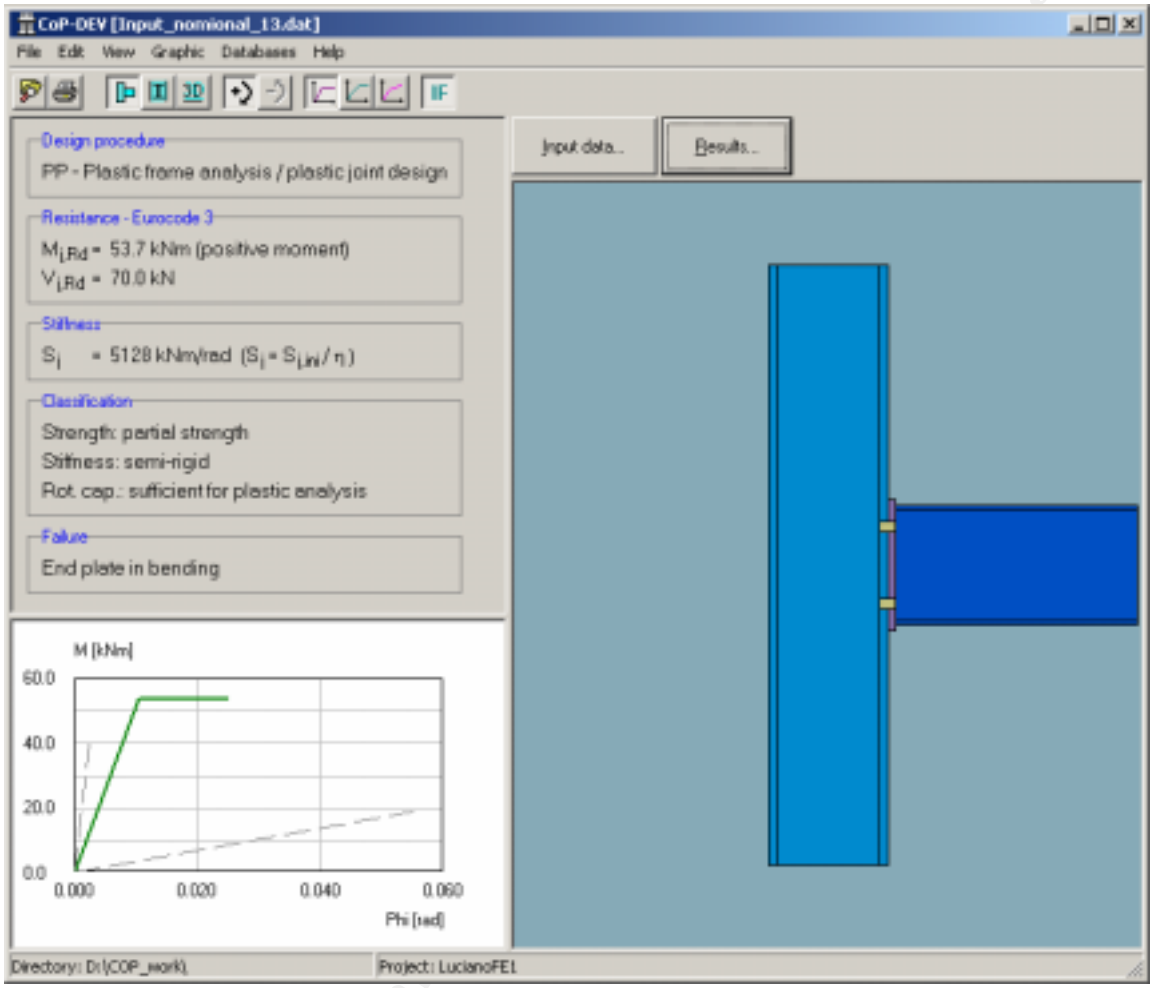
3. References

[1] ENV 1993-1-1 : 1992, Eurocode 3: Design of steel structures.
Part 1.1: General rules and rules for buildings,
CEN, Brussels 1992.

[2] ENV 1993-1-1 : 1992/A2, October 1998.
Revised Annex J of Eurocode 3, "Joints in Building Frames",
CEN, Brussels, October 1998.

FE1 modified endplate=13mm, nominal properties, no safety factors

Design of joints in building frames
according to Eurocode 3 - revised Annex J



1. INPUT DATA

1.1 PROJECT DATA

```
project .....................: MSc in Civil Engineering - Structures
structure ...................: FE1
joint .......................: Flush End Plate Tested by Luciano Lima in Coimbra
joint id ....................: FE1 - Nominal Endplate 13mm
engineer ....................: LB
date ........................: 28-03-2003

design procedure ............: plastic analysis / plastic joint design
```

environment .....: not corrosive
framing .....: not braced

1.2 main joint data

beam : IPE 240, S 275
column : HEB 240, S 275
flush end plate : 264 X 160 X 13, S 275

1.3 mechanical characteristics

	yield strength N/mm²	ultimate strength N/mm²
beam web .....:	275.00	430.00
beam flange .....:	275.00	430.00
column web .....:	275.00	430.00
column flange .....:	275.00	430.00
end plate .....:	275.00	430.00
bolts in tension .....:	900.00	1000.00

1.4 geometrical characteristics

1.4.1 beam : IPE 240, S 275

depth .....:	240.00 mm
width .....:	120.00 mm
thickness of the flange .....:	9.80 mm
thickness of the web .....:	6.20 mm
root radius .....:	15.00 mm
inertia .....:	3891.63 cm4
area .....:	39.12 cm²
length of the beam connected to the column .....:	6000.00 mm
beam inclination .....:	0.00 °

1.4.2 column : HEB 240, S 275

depth .....:	240.00 mm
width .....:	240.00 mm
thickness of the flange .....:	17.00 mm
thickness of the web .....:	10.00 mm
root radius .....:	21.00 mm
inertia .....:	11259.30 cm4
area .....:	105.99 cm²

1.4.3 end plate 264 X 160 X 13, S 275

vertical distance between the beam flange and the edge of the end plate .....:	12.00 mm
vertical distance between the first bolt row and the edge of the end plate .....:	54.00 mm
horizontal distance between the bolts .....:	96.00 mm
horizontal distance between the bolts and the edge of the end plate .....:	32.00 mm

1.4.4 bolts in tension 10.9

```
resistant area ..........................................:      245.00 mm²
diameter of the shank ...................................:       20.00 mm
diameter of the holes ...................................:       22.00 mm
thickness of the bolt head ..............................:       13.00 mm
thickness of the nut ....................................:       16.00 mm
total thickness of the washer(s) per bolt ...............:        4.00 mm
diameter of the washers .................................:       37.00 mm
```

1.4.5 welds

```
thickness of the weld connecting the beam flange ........:        8.00 mm
thickness of the weld connecting the beam web ...........:        8.00 mm
```

1.5 safety factors

```
gamma M0 ................................................:        1.00
gamma M1 ................................................:        1.10
gamma Mb ................................................:        1.00
gamma Mw ................................................:        1.00
```

2. JOINT PROPERTIES FOR POSITIVE MOMENTS

2.1 CALCULATION OF THE COMPONENTS

2.1.1 column web panel in shear

```
sheared area of the column ..................: Avc    =       33.23 cm²
beta coefficient ..................... ( J.2.6.3 ) : BETA   =        1.00
plastic resistance of the column web panel .....: VwpRd  =      474.77 kN
   ( J.3.5.1)
resistance : vwprd / beta ......................: FwpRd  =      474.77 kN

stiffness coefficient ............. ( Form. J.39 ) : k1     =        6.54 mm
```

2.1.2 column web in compression

```
effective width ................... ( Form. J.20 ) : l1     =      248.43 mm
                                                    l2     =      236.11 mm
                                                 => beff   =      236.11 mm

coefficient for stress interaction .. ( Table J.5 ) : RHO    =        0.78
longitudinal compressive stress in the web adjacent
   to the root radius ..........................: Sigma  =        0.00 N/mm²
reduction factor .................. ( Form. J.22 ) : kwc    =        1.00

strength : ( Form. J.17 )
   * buckling of the web :
     slenderness ...................................: LAMBDA =        0.66
     strength ......................................: Fc2    =      504.50 kN

strength ...........................................: FcwcRd =      504.50 kN
```

```
stiffness coefficient ..... ( Form. J.40 ) : k2     =       10.08 mm
```

2.1.3 column flange in bending

```
geometrical parameters ..... ( Fig. J.25 ) : e      =       72.00 mm
======================                       emin   =       32.00 mm
                                             m      =       26.20 mm
                                             n      =       32.00 mm
                                             ew     =        9.25 mm
```

2.1.3.1 effective length of the equivalent t-stub (Tables J.6 - J.7)

```
   * circular patterns :
        2 Pi m .....................................: l      =      164.62 mm
   * other patterns :
        4 m + 1.25 e ...............................: l      =      194.80 mm

   for all bolt rows :
   * circular patterns ............................: leff   =      164.62 mm
   * other patterns ...............................: leff   =      194.80 mm
```

2.1.3.2 strength

```
( J.3.5.4.2 )
design resistance of a bolt ....... ( Table 6.5.3 ) : BtRd   =      220.50 kN

*  bolt row nb 1

   longitudinal compressive stress in the flange ...: Sigma  =        0.00 N/mm²
   reduction factor ................ ( Form. J.29 ) : kfc    =        1.00

   mode of collapse for equivalent T-stub ( J.3.2.1 )

   design plastic resistance of the T-stub ( Form. J.7 )
      for complete yielding of the flange ..........: Mpl1Rd =     3270.78 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =     3870.43 Nm

   mode 1 : complete yielding of the flange ........: F1Rd   =      499.36 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      375.48 kN
   mode 3 : bolts failure ..........................: F3Rd   =      441.00 kN
            ( Form. J.4 - J.5 - J.6 )

   strength ....................................: FtRd(1)  =      375.48 kN
```

2.1.3.3 stiffness

```
*  effective length of the equivalent t-stub
   bolt rows are considered individually or as part of a group

   bolt row nb  1 ..............................: beff(1)  =      164.62 mm

*  stiffness coefficient ( Form. J.42 )

   bolt row nb  1 ..............................: k3(1)    =       38.22 mm
```

2.1.4 column web in tension

2.1.4.1 strength

bolt row nb	coefficient for stress interaction (Table J.5)	strength (kN)
1	0.83	445.36

2.1.4.2 stiffness

bolt row nb 1 ..... : k4(1) = 7.03 mm

2.1.5 end plate in bending

geometrical parameters ..... (Fig. J.28) : e = 72.00 mm
m = 35.85 mm

bolt row nb 1 (below the top beam flange) ..... : m1 = 35.85 mm
m2 = 23.15 mm
determination of the alpha coefficient ..... : Lambda1= 0.53
(Fig. J.27) Lambda2= 0.34
ALPHA = 5.98

bolt row nb 1 (up to the bottom beam flange) .. : m1 = 35.85 mm
m2 = 179.15 mm
determination of the alpha coefficient ..... : Lambda1= 0.53
(Fig. J.27) Lambda2= 2.64
ALPHA = 5.13

2.1.5.1 effective length of the equivalent t-stub (Tables J.8) :

bolt row nb 1 (influence of the upper beam flange)
* circular patterns :
2 Pi m1 ..... : leff = 225.25 mm
* other patterns :
Alpha m1 ..... : leff = 214.48 mm

bolt row nb 2 (not influenced by the beam flanges)
* circular patterns :
2 Pi m1 ..... : leff = 0.00 mm
* other patterns :
4 m1 + 1.25 e ..... : leff = 0.00 mm

bolt row nb 1 (influence of the lower beam flange)
* circular patterns :
2 Pi m1 ..... : leff = 225.25 mm
* other patterns :
Alpha m1 ..... : leff = 214.48 mm

2.1.5.2 strength

* bolt row nb 1

mode of collapse for equivalent T-stub (J.3.2.1)

design plastic resistance of the T-stub (Form. J.7)

```
      for complete yielding of the flange ..........: Mpl1Rd =     2491.95 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =     2491.95 Nm

   mode 1 : complete yielding of the flange ........: F1Rd   =      278.05 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      281.45 kN
   mode 3 : bolts failure ..........................: F3Rd   =      441.00 kN
            ( Form. J.4 - J.5 - J.6 )

   strength ....................................: FtepRd(1)=      278.05 kN
```

2.1.5.3 stiffness

```
*  effective length of the equivalent t-stub
   bolt rows are considered individually or as part of a group

   bolt row nb  1 ..............................: leff(1) =      112.62 mm

*  stiffness coefficient ( Form. J.43 )

   bolt row nb  1 ..............................: k5(1)  =        4.57 mm
```

2.1.5.4 bolts in tension

```
length of the bolt .................. ( J.4.4.10 ) : Lb     =       48.50 mm
strength ........................... ( Table 6.5.3 ) : BtRd   =      220.50 kN
stiffness coefficient .............. ( Form. J.45 ) : k7     =        8.08 mm
```

2.1.6 beam flange in compression

```
moment resistance of the beam cross-section ........: McRd   =      100.83 kNm
strength ........................... ( Form. J.30 ) : FcfbRd =      438.00 kN
```

2.1.7 beam web in tension

```
effective width
   => equal to the ones of the end plate in bending
```

2.1.7.1 strength

bolt row nb		strength (kN) (Form. J.31) FtwbRd(i)
1	:	365.68

2.2 ASSEMBLY OF THE COMPONENTS

2.2.1 strength (Fig. J.34)

2.2.1.1 bolt row nb 1

```
                                                              strength (kN)

   column web panel in shear ..................................:     474.77
```

```
   column web in compression ..................................:      504.50
   column flange in bending ...................................:      375.48
   column web in tension ......................................:      445.36
   end plate in bending .......................................:      278.05
   bolts in tension ...........................................:      441.00
   beam flange in compression .................................:      438.00
   beam web in tension ........................................:      365.68
                                                                    ---------
   resistance of bolt row nb  1 ....................: Frd(1) =      278.05 kN


plastic distribution of the internal forces
```

2.2.1.2 summary

```
   resistance of bolt row nb  1 ....................: FRd(1) =      278.05 kN

   moment resistance (weld failure disregarded) .....: MRdj   =       53.69 kNm
   moment resistance of the welds ...................: MRdw   =      129.09 kNm
                                                                    ---------
   moment resistance ..................... ( J.3.6 ) :                53.69 kNm

   elastic moment resistance ............. ( J.2.1.2 ) : Me     =       35.79 kNm
```

2.2.2 stiffness

2.2.2.1 determination of the equivalent stiffness coefficient

```
                        effective stiffness
                        coefficient (mm)          lever arm of internal forces
                        ( Form. J.36 )

   bolt row nb  1 : keff,1 =       1.96               h 1 =      193.10

   lever arm of internal forces ..... ( Form. J.38 ) : z      =      193.10 mm
   equivalent stiffness coefficient ... ( Form. J.36 ) : keq    =        1.96 mm
```

2.2.2.2 percentages of flexibility

```
   the flexibility of each bolt row is the relative flexibility of each
   bolt row in comparison with the other ones regardless of the lever arms

   for the sheared panel                20 %
   for the compression zone             13 %
   for the tension zone                 67 %
      * bolt row nb 1                          ** %
           end plate in bending                                  43 %
           bolts in tension                                      24 %
```

2.2.2.3 summary

```
   initial stiffness .................. ( Form. J.34 ) : Sji    =    10256.87 kNm/rad
   idealized stiffness . ( J.2.1.2 - J.2.1.4 - T.J.3 ) : Sjn    =     5128.44 kNm/rad
   secant stiffness ................... ( Form. J.34 ) : Sjs    =     3432.17 kNm/rad
```

2.2.3 shear resistance

```
shear resistance of one bolt row .. ( Table 6.5.3 ) : FvRd   =      245.00 kN


column flange in bearing ( Table 6.5.3 ):
                                          p1/(3d0)-0.25 =      151.27
                                          fub / fu      =        2.33
                                          =>     ALPHA  =        1.00
   bearing resistance of one bolt row ..............: FbRd   =      731.00 kN

end plate in bearing :
                                          p1/(3d0)-0.25 =      151.27
                                          fub / fu      =        2.33
                                          =>     ALPHA  =        1.00
   bearing resistance of one bolt row ..............: FbRd   =      530.54 kN

the shear resistance of a bolt row submited to both
   shear and tensile forces is reduced by a factor 0.4/1.4
               ( J.3.1.2.(2b) )

shear resistance of the bolt row n°  1 .........: Vrd(1) =       70.00 kN

shear resistance of the welds
   correlation factor ............. ( 6.6.5.3.(5) ) : BETA   =        0.85
   length of the weld ..............................: a      =      190.40 mm
   shear resistance of the welds .. ( 6.6.5.3.(4) ) : FwRd   =      889.77 kN

design shear resistance of the joint ..............: VRd    =       70.00 kN
```

2.2.4 collapse mode

```
bolt row nb 1 : end plate in bending

sufficient rotation capacity for plastic global analysis
```

2.3 DESIGN PROPERTIES OF THE JOINT FOR PLASTIC ANALYSIS / PLASTIC JOINT DESIGN

```
design moment resistance ............................: MRd    =       53.69 kNm

initial stiffness ................. ( Form. J.34 ) : Sji    =    10256.87 kNm/rad
idealized stiffness . ( J.2.1.2 - J.2.1.4 - T.J.3 ) : Sjn    =     5128.44 kNm/rad
```

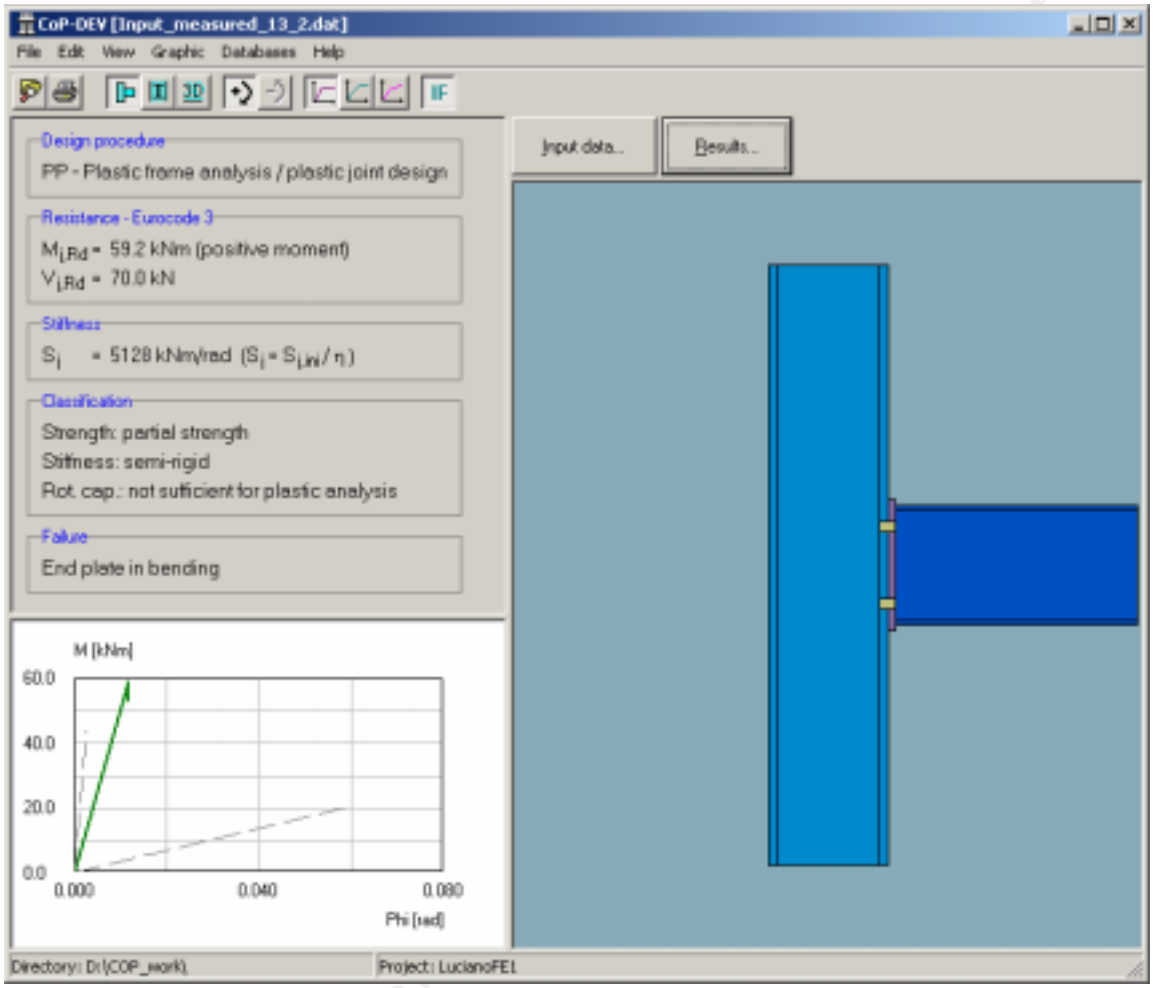
3. References

[1] ENV 1993-1-1 : 1992, Eurocode 3: Design of steel structures.
Part 1.1: General rules and rules for buildings,
CEN, Brussels 1992.

[2] ENV 1993-1-1 : 1992/A2, October 1998.
Revised Annex J of Eurocode 3, "Joints in Building Frames",
CEN, Brussels, October 1998.

FE1 modified endplate=13 mm, measured properties, no safety factors

Design of joints in building frames
according to Eurocode 3 - revised Annex J



1. INPUT DATA

1.1 PROJECT DATA

```
project .....................: MSc in Civil Engineering - Structures
structure ...................: FE1
joint .......................: Flush End Plate Tested by Luciano Lima in Coimbra
joint id ....................: FE1 - measured_ endplate 13mm
engineer ....................: LB
date ........................: 28-03-2003

design procedure ............: plastic analysis / plastic joint design
```

environment .....: not corrosive
framing .....: not braced

1.2 main joint data

beam : IPE 240, S 275
column : HEB 240, S 275
flush end plate : 264 X 160 X 13, S 275

1.3 mechanical characteristics

	yield strength N/mm²	ultimate strength N/mm²
beam web	363.40	430.00
beam flange	340.10	430.00
column web	372.00	430.00
column flange	342.90	430.00
end plate	369.40	430.00
bolts in tension	900.00	1000.00

1.4 geometrical characteristics

1.4.1 beam : IPE 240, S 275

depth	240.00 mm
width	120.00 mm
thickness of the flange	9.80 mm
thickness of the web	6.20 mm
root radius	15.00 mm
inertia	3891.63 cm4
area	39.12 cm²
length of the beam connected to the column	6000.00 mm
beam inclination	0.00 °

1.4.2 column : HEB 240, S 275

depth	240.00 mm
width	240.00 mm
thickness of the flange	17.00 mm
thickness of the web	10.00 mm
root radius	21.00 mm
inertia	11259.30 cm4
area	105.99 cm²

1.4.3 end plate 264 X 160 X 13, S 275

vertical distance between the beam flange and the edge of the end plate	12.00 mm
vertical distance between the first bolt row and the edge of the end plate	54.00 mm
horizontal distance between the bolts	96.00 mm
horizontal distance between the bolts and the edge of the end plate	32.00 mm

1.4.4 bolts in tension 10.9

```
resistant area ..........................................:      245.00 mm²
diameter of the shank ...................................:       20.00 mm
diameter of the holes ...................................:       22.00 mm
thickness of the bolt head ..............................:       13.00 mm
thickness of the nut ....................................:       16.00 mm
total thickness of the washer(s) per bolt ...............:        4.00 mm
diameter of the washers .................................:       37.00 mm
```

1.4.5 welds

```
thickness of the weld connecting the beam flange ........:        8.00 mm
thickness of the weld connecting the beam web ...........:        8.00 mm
```

1.5 safety factors

```
gamma M0 ................................................:        1.00
gamma M1 ................................................:        1.00
gamma Mb ................................................:        1.00
gamma Mw ................................................:        1.00
```

2. JOINT PROPERTIES FOR POSITIVE MOMENTS

2.1 CALCULATION OF THE COMPONENTS

2.1.1 column web panel in shear

```
sheared area of the column ..................: Avc    =       33.23 cm²
beta coefficient ..................... ( J.2.6.3 ) : BETA   =        1.00
plastic resistance of the column web panel .....: VwpRd  =      642.24 kN
   ( J.3.5.1)
resistance : vwprd / beta ......................: FwpRd  =      642.24 kN

stiffness coefficient ............. ( Form. J.39 ) : k1     =        6.54 mm
```

2.1.2 column web in compression

```
effective width ................... ( Form. J.20 ) : l1     =      248.43 mm
                                                    l2     =      236.11 mm
                                                 => beff   =      236.11 mm

coefficient for stress interaction .. ( Table J.5 ) : RHO    =        0.78
longitudinal compressive stress in the web adjacent
   to the root radius ..........................: Sigma  =        0.00 N/mm²
reduction factor .................. ( Form. J.22 ) : kwc    =        1.00

strength : ( Form. J.17 )
   * buckling of the web :
     slenderness ...................................: LAMBDA =        0.77
     strength ......................................: Fc2    =      682.44 kN

strength ...........................................: FcwcRd =      632.95 kN
```

```
stiffness coefficient ..... ( Form. J.40 ) : k2     =       10.08 mm
```

2.1.3 column flange in bending

```
geometrical parameters ..... ( Fig. J.25 ) : e      =       72.00 mm
======================                       emin   =       32.00 mm
                                             m      =       26.20 mm
                                             n      =       32.00 mm
                                             ew     =        9.25 mm
```

2.1.3.1 effective length of the equivalent t-stub (Tables J.6 - J.7)

```
   * circular patterns :
        2 Pi m ..................................: l      =      164.62 mm
   * other patterns :
        4 m + 1.25 e ............................: l      =      194.80 mm

   for all bolt rows :
   * circular patterns .........................: leff   =      164.62 mm
   * other patterns ............................: leff   =      194.80 mm
```

2.1.3.2 strength

```
( J.3.5.4.2 )
design resistance of a bolt ....... ( Table 6.5.3 ) : BtRd   =      220.50 kN

*  bolt row nb 1

   longitudinal compressive stress in the flange ...: Sigma  =        0.00 N/mm²
   reduction factor ................ ( Form. J.29 ) : kfc    =        1.00

   mode of collapse for equivalent T-stub ( J.3.2.1 )

   design plastic resistance of the T-stub ( Form. J.7 )
      for complete yielding of the flange ..........: Mpl1Rd =     4078.37 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =     4826.08 Nm

   mode 1 : complete yielding of the flange ........: F1Rd   =      622.65 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      408.32 kN
   mode 3 : bolts failure ..........................: F3Rd   =      441.00 kN
            ( Form. J.4 - J.5 - J.6 )

   strength ....................................: FtRd(1)  =      408.32 kN
```

2.1.3.3 stiffness

```
*  effective length of the equivalent t-stub
   bolt rows are considered individually or as part of a group

   bolt row nb  1 ..............................: beff(1)  =      164.62 mm

*  stiffness coefficient ( Form. J.42 )

   bolt row nb  1 ..............................: k3(1)    =       38.22 mm
```

2.1.4 column web in tension

2.1.4.1 strength

bolt row nb	coefficient for stress interaction (Table J.5)	strength (kN)
1	0.83	602.45

2.1.4.2 stiffness

bolt row nb 1 .....: k4(1) = 7.03 mm

2.1.5 end plate in bending

geometrical parameters ..... (Fig. J.28) : e = 72.00 mm
==========
m = 35.85 mm

bolt row nb 1 (below the top beam flange) .....: m1 = 35.85 mm
m2 = 23.15 mm
determination of the alpha coefficient .....: Lambda1= 0.53
(Fig. J.27) Lambda2= 0.34
ALPHA = 5.98

bolt row nb 1 (up to the bottom beam flange) ..: m1 = 35.85 mm
m2 = 179.15 mm
determination of the alpha coefficient .....: Lambda1= 0.53
(Fig. J.27) Lambda2= 2.64
ALPHA = 5.13

2.1.5.1 effective length of the equivalent t-stub (Tables J.8) :

bolt row nb 1 (influence of the upper beam flange)
* circular patterns :
2 Pi m1 .....: leff = 225.25 mm
* other patterns :
Alpha m1 .....: leff = 214.48 mm

bolt row nb 2 (not influenced by the beam flanges)
* circular patterns :
2 Pi m1 .....: leff = 0.00 mm
* other patterns :
4 m1 + 1.25 e .....: leff = 0.00 mm

bolt row nb 1 (influence of the lower beam flange)
* circular patterns :
2 Pi m1 .....: leff = 225.25 mm
* other patterns :
Alpha m1 .....: leff = 214.48 mm

2.1.5.2 strength

* bolt row nb 1

mode of collapse for equivalent T-stub (J.3.2.1)

design plastic resistance of the T-stub (Form. J.7)

```
      for complete yielding of the flange .....: Mpl1Rd =     3347.37 Nm
      for bolt failure with yielding of the flange .: Mpl2Rd =     3347.37 Nm

   mode 1 : complete yielding of the flange .....: F1Rd   =      373.50 kN
   mode 2 : bolt failure with yield. of the fl. ....: F2Rd   =      306.66 kN
   mode 3 : bolts failure .....................: F3Rd   =      441.00 kN
            ( Form. J.4 - J.5 - J.6 )

   strength ..................................: FtepRd(1)=      306.66 kN
```

2.1.5.3 stiffness

```
*  effective length of the equivalent t-stub
   bolt rows are considered individually or as part of a group

   bolt row nb  1 ............................: leff(1) =      112.62 mm

*  stiffness coefficient ( Form. J.43 )

   bolt row nb  1 ............................: k5(1)  =        4.57 mm
```

2.1.5.4 bolts in tension

```
length of the bolt ................. ( J.4.4.10 ) : Lb     =       48.50 mm
strength ........................... ( Table 6.5.3 ) : BtRd   =      220.50 kN
stiffness coefficient .............. ( Form. J.45 ) : k7     =        8.08 mm
```

2.1.6 beam flange in compression

```
moment resistance of the beam cross-section .....: McRd   =      127.89 kNm
strength ......................... ( Form. J.30 ) : FcfbRd =      555.57 kN
```

2.1.7 beam web in tension

```
effective width
   => equal to the ones of the end plate in bending
```

2.1.7.1 strength

bolt row nb	strength (kN) (Form. J.31) FtwbRd(i)
1 :	483.23

2.2 ASSEMBLY OF THE COMPONENTS

2.2.1 strength (Fig. J.34)

2.2.1.1 bolt row nb 1

```
                                                          strength (kN)

column web panel in shear .................................:      642.24
```

```
   column web in compression ..................................:      632.95
   column flange in bending ...................................:      408.32
   column web in tension ......................................:      602.45
   end plate in bending .......................................:      306.66
   bolts in tension ...........................................:      441.00
   beam flange in compression .................................:      555.57
   beam web in tension ........................................:      483.23
                                                                   ---------
   resistance of bolt row nb  1 ....................: Frd(1) =      306.66 kN


plastic distribution of the internal forces
```

2.2.1.2 summary

```
   resistance of bolt row nb  1 ....................: FRd(1) =      306.66 kN

   moment resistance (weld failure disregarded) .....: MRdj   =       59.22 kNm
   moment resistance of the welds ...................: MRdw   =      129.09 kNm
                                                                   ---------
   moment resistance ..................... ( J.3.6 ) :                59.22 kNm

   elastic moment resistance ............. ( J.2.1.2 ) : Me     =       39.48 kNm
```

2.2.2 stiffness

2.2.2.1 determination of the equivalent stiffness coefficient

```
                        effective stiffness
                        coefficient (mm)          lever arm of internal forces
                        ( Form. J.36 )

   bolt row nb  1 : keff,1 =       1.96               h 1 =      193.10

   lever arm of internal forces ..... ( Form. J.38 ) : z      =      193.10 mm
   equivalent stiffness coefficient ... ( Form. J.36 ) : keq    =        1.96 mm
```

2.2.2.2 percentages of flexibility

```
   the flexibility of each bolt row is the relative flexibility of each
   bolt row in comparison with the other ones regardless of the lever arms

   for the sheared panel                20 %
   for the compression zone             13 %
   for the tension zone                 67 %
      * bolt row nb 1                          ** %
           end plate in bending                                  43 %
           bolts in tension                                      24 %
```

2.2.2.3 summary

```
   initial stiffness .................. ( Form. J.34 ) : Sji    =    10256.87 kNm/rad
   idealized stiffness . ( J.2.1.2 - J.2.1.4 - T.J.3 ) : Sjn    =     5128.44 kNm/rad
   secant stiffness ................... ( Form. J.34 ) : Sjs    =     3432.17 kNm/rad
```

2.2.3 shear resistance

```
shear resistance of one bolt row .. ( Table 6.5.3 ) : FvRd   =      245.00 kN


column flange in bearing ( Table 6.5.3 ):
                                          p1/(3d0)-0.25 =      151.27
                                          fub / fu      =        2.33
                                          =>     ALPHA  =        1.00
   bearing resistance of one bolt row ..............: FbRd   =      731.00 kN

end plate in bearing :
                                          p1/(3d0)-0.25 =      151.27
                                          fub / fu      =        2.33
                                          =>     ALPHA  =        1.00
   bearing resistance of one bolt row ..............: FbRd   =      530.54 kN

the shear resistance of a bolt row submited to both
   shear and tensile forces is reduced by a factor 0.4/1.4
               ( J.3.1.2.(2b) )

shear resistance of the bolt row n°  1 .........: Vrd(1) =       70.00 kN

shear resistance of the welds
   correlation factor ............. ( 6.6.5.3.(5) ) : BETA   =        0.85
   length of the weld ..............................: a      =      190.40 mm
   shear resistance of the welds .. ( 6.6.5.3.(4) ) : FwRd   =      889.77 kN

design shear resistance of the joint ..............: VRd    =       70.00 kN
```

2.2.4 collapse mode

```
bolt row nb 1 : end plate in bending

not enough rotation capacity for plastic global analysis
```

2.3 DESIGN PROPERTIES OF THE JOINT FOR PLASTIC ANALYSIS / PLASTIC JOINT DESIGN

```
design moment resistance ............................: MRd    =       59.22 kNm

initial stiffness .................. ( Form. J.34 ) : Sji    =    10256.87 kNm/rad
idealized stiffness . ( J.2.1.2 - J.2.1.4 - T.J.3 ) : Sjn    =     5128.44 kNm/rad
```

3. References

[1] ENV 1993-1-1 : 1992, Eurocode 3: Design of steel structures.
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CEN, Brussels 1992.

[2] ENV 1993-1-1 : 1992/A2, October 1998.
Revised Annex J of Eurocode 3, "Joints in Building Frames",
CEN, Brussels, October 1998.