9.2.0 DESIGN ASSUMPTIONS

2.1 CODES AND STANDARDS

- PN-82/B-02000 Actions on building structures. Principles of the establishment of the values.
- PN-82/B-02001 Actions on building structures. Permanent actions.
- PN-82/B-02003 Actions on building structures. Variable actions during exploitation and assembling.
- PN-80/B-02010 Loads in static calculations. Snow loads.
- PN-77/B-02011 Loads in static calculations. Wind loads.
- PN-76/B-03001 Building structures and soils. Design principles.
- PN-84/B-03264 Concrete, reinforced concrete and prestressed concrete. Design rules.
- PN-80/B-01800 Protection against corrosion in building. Concrete and reinforced concrete structures. Classification and determination of environment.

2.2 CONCRETE STRUCTURE

2.2.1 CONSEQUENCE FACTOR

Consequence factor γn = 1,0

2.2.2 ENVIRONMENTAL CONDITIONS

Environmental class : A

2.2.3 CONCRETE

Construction	R_b^G (N/mm^2)	R_{bK} (N/mm^2)	R_b (N/mm^2)	R_{bz} (N/mm^2)
Columns below level 173.900	35,0	25,7	19,8	1,26
Columns above level 173.900	30,0	22,2	17,1	1,15
Other structural elements	30,0	22,2	17,1	1,15

Modulus of elasticity :

E_b = 32400 MPa , concrete class B30

E_b = 34400 MPa , concrete class B35

2.2.4 REINFORCEMENT

Class and type of steel	Designation of steel	R_{aK} (N/mm^2)	R_a (N/mm^2)
A-III, round, ribbed	34GS	410	350

2.2.5 CONCRETE COVER

In colums, beams and plates : 25 mm

2.2.6 CRACK WIDTH

Crack width : 0,3 mm

9.3.0 LOADS

3.1 DEAD LOAD

3.1.1 General
Refer to enclosure, drawings no. W2HT/BK003d, -004d, -005d, -006d, -007d, -008d, -011b and 012a, all dated 23.02.96.

3.1.2 1st level, North
Screed layer due to gully 1 kN/m²
wavstwa spadkowa

3.1.3 4th level
Screed layer 1.4 kN/m²

3.1.4 5th level
Screed layer due to gully 1 kN/m²

3.1.5 6th level
Screed layer due to gully 1 kN/m²

3.2 LIVE LOAD

3.2.1 General
Refer to enclosure, drawings no. W2HT/BK003d, -004d, -005d, -006d, -007d, -008d, -011b and 012a, all dated 23.02.96.

3.2.2 Wind load, according to PN-77/B-02011
Area I
- Basis wind speed = 20 m/s
- Basis wind load q_K = 0,25 kN/m²
- Characteristic wind load:
  $W_K = q_K * C_e * C * \beta$

Where:
- C_e is a height factor dependent on the terrain.
  Class A
  Terrain is assumed:
  0 - 10 m: $_e = 1.0$
  10 - 20 m: $C_e = 0.8 + 0.02 * Z$
  20 - 40 m: $C_e = 0.9 + 0.015 * Z$
  40 - 100 m: $C_e = 1.23 + 0.0067 * Z$

- C is a shape factor.
- β is a dynamic factor (β = 1,8 for non-sensiti-vestructures).

3.2.3 Snow load, according to PN 80/B-2010

Area II

- Q_K = 0,9 kN/m²
- $S_K = Q_K * C$

Where:

- C = Factor to be applied dependent of slope and shape of roof.

Flat roof: C = 0,8

- S_K = 0,9 * 0,8 = 0,72 kN/m²

3.2.4 Temperature stresses

µ friction (Glacier) = 5%

Design temperature:

Erection temperature + 10°C

Max. temperature + 180°C

Min. temperature - 20°C

- (According to FLSm)

3.2.5 Roof, live load = 1.0 kN/m²

3.3 LOAD COMBINATIONS

1. Ultimate limit state
   $\sum \gamma_{fi} * G_{ki} + \sum \Psi_{oi} * \gamma_{fi} * Q_{ki}$

2. Accidental load
   $\sum \gamma_{fi} * G_{ki} + 0,8 \sum \gamma_{fi} * Q_{ki} + F_a$

3. Serviceability limit state (basic combination)
   $\sum G_{ki} + Q_k$

4. Serviceability limit state (long term)
   $\sum G_{ki} + \sum \Psi_{di} * Q_{ki}$

	1.1	1.2	2.0	3.0	4.0
DEAD LOAD	1,1	0,9	1,1	1,0	1,0
LIVE LOAD	1,3	1,3	1,3	1,0	0,35
SNOW LOAD	1,4	1,4	1,4	1,0	0,50
WIND LOAD	1,3	1,3	1,3	1,0	-
ACCIDENTAL LOAD	-	-	1,0	-	-

LOAD NUMBER	Ψ_o
1.	1,0
2.	0,9
3.	0,8
4.	0,7

9.4.0 SLABS AND BEAMS

The calculation of slabs and beams are carried out for each floor plan separately.

For each floor plan geometry and loads are listed whereupon slabs and beams are calculated.

The equipment loads informed by FLSm are used, and shown in the live load summary.

These loads are distributed in two ways:

1) To be used in the **slab design**. Normally the surface load directly under the equipment in question is used on the entire slab.

2) To be used in **beam design**, where the loads are distributed in such a way that they can be used to find the reactions on the beams, without being too much on the safe side.

The slabs are calculated by using the loads listed on the page "Live loads used in slab design" + dead load from slab + load from screed layer if any.

K. W. Johansen yield-line theory has been used to calculate the slabs. In the calculations the reinforcement at the top of the slab is half the reinforcement at bottom.

The beams are calculated by using the loads listed under "Live loads used in beam design" + load from screed layer if any + dead load of beam.

Line loads from slabs and equipment are found by using the spread sheets where the slabs are calculated.

The beams are calculated with the use of elasticity theory. They are loaded with all possible load combinations. The FEM-programme GTSTRUDL is used to calculate the envelope of moment and shear force from all the load combinations.

Bending and shear reinforcement are calculated on the basis of these envelope plots and acc. to Polish standard.

For variation of bending reinforcement along the beam axis, refer detailed curves in appendix, showing nos. of bars in top and bottom of the cross section along the element.

The order of calculation is as follows:

1) Tertiary beams are calculated, if any.

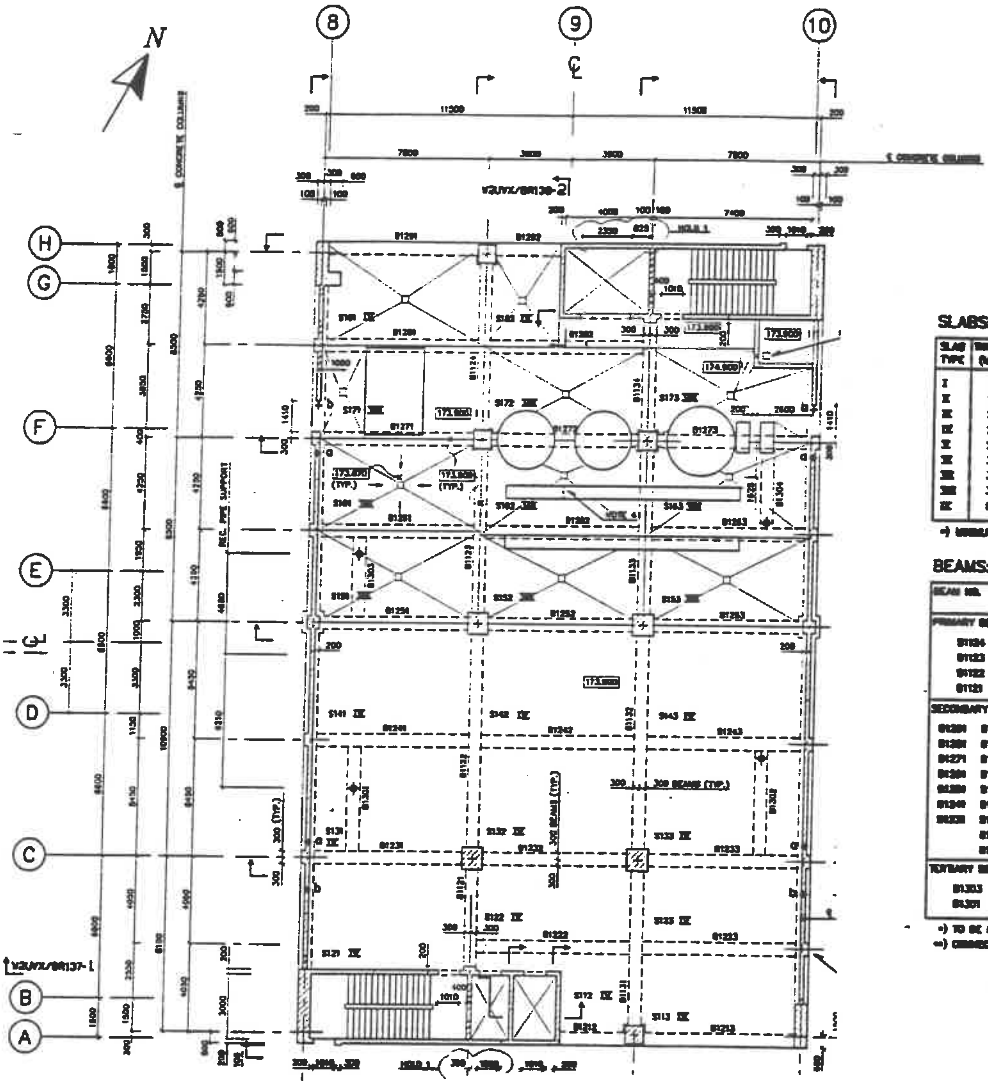
2) Secondary beams are calculated, with the loads from the tertiary beams added, if any.

3) Primary beams are calculated with the loads from the secondary beams added.

Deflections are calculated using the load combination with load on all spans.

4.1 LEVEL 1 (+173.900)

4.1.1 GEOMETRY



SLABS:

SLAB TYPE	THICKNESS (MIN.) *)	REINFORCEMENT BOTTOM LAYER	REINFORCEMENT TOP LAYER
I	150	Ø12/200 BD	Ø12/400 BD
II	150	Ø12/150 BD	Ø12/300 BD
III	200	Ø12/200 BD	Ø12/400 BD
IV	200	Ø16/200 BD	Ø16/400 BD
V	250	Ø16/150 BD	Ø16/300 BD
VI	300	Ø12/200 BD	Ø12/400 BD
VII	300	Ø16/200 BD	Ø16/400 BD
VIII	350	Ø16/150 BD	Ø16/300 BD
IX	800	Ø25/125 BD	Ø25/250 BD

*) MINIMUM THICKNESS

BEAMS:

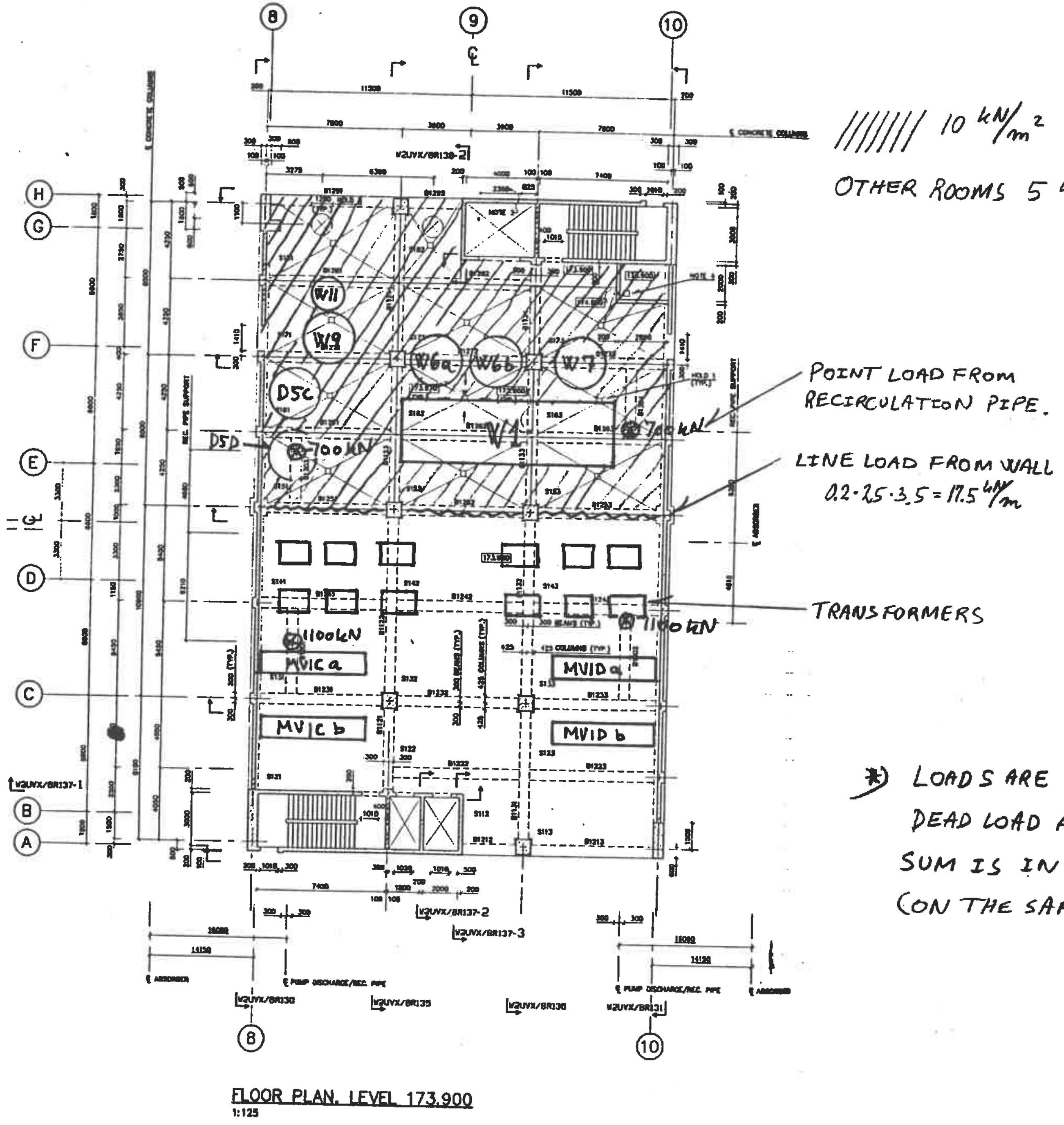
BEAM NO.			HEIGHT (MIN.) *)	REINFORCEMENT
PRIMARY BEAMS				
B1124	B1134		1450	GENERAL REINFORCEMENT REF. DWG. W2UVX/BR300
B1123	B1133		1450	
B1122	B1132		1450	
B1121	B1131		1450	
SECONDARY BEAMS				
B1291	B1292		1150	
B1281	B1282		1150	L (LEFT) / R (RIGHT)
B1271	B1272	B1273	1150	
B1261	B1262	B1263	1150	
B1251	B1252	B1253	1150	ORIENTATION USED IN THE ABOVE DWG.
B1241	B1242	B1243	950	
B1231	B1232	B1233	950	
	B1222	B1223	750	
	B1212	B1213	750	
TERTIARY BEAMS **)				
B1303	B1304		650	
B1301	B1302		650	

*) TO BE MEASURED FROM LEVEL 173.900

**) CONNECTION TO SECONDARY BEAM REF. DWG. W2UVX/BR300

4.1.2 LOADS

4.1.2.1 LIVE LOAD SUMMARY



////// 10 kN/m² *)

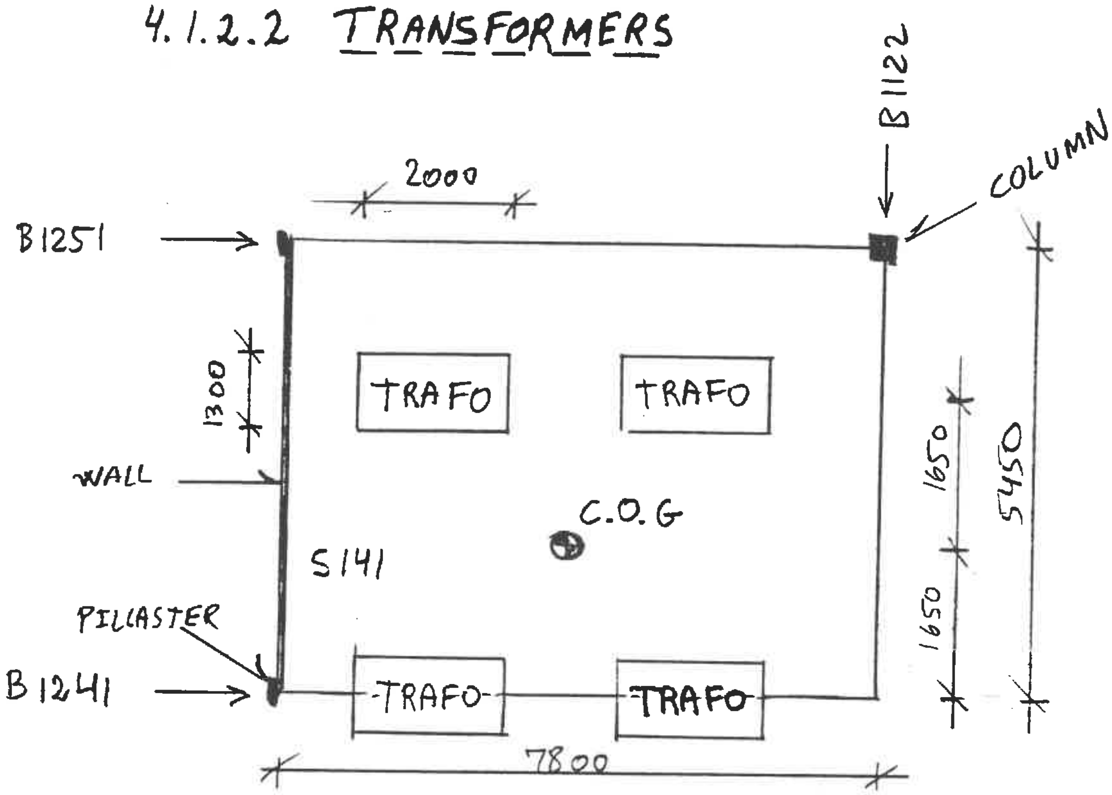
OTHER ROOMS 5 kN/m² *)

CHARACTERISTIC LOADS FROM EQUIPMENT *):

W1	:	1304 kN
W6a, W6b	:	404 kN
W7	:	370 kN
W9	:	700 kN
W11	:	39 kN
W12	:	47 kN
TRANSFORMERS	:	35 kN EACH.
MVIC a, MVIC b	:	72 kN
MVID a, MVID b	:	72 kN
D5C, D5D	:	290 kN

*) LOADS ARE TAKEN FROM FLSm LOAD PLANS. DEAD LOAD AND LIVE LOAD ARE ADDED, AND THIS SUM IS IN THE FOLLOWING CALCULATIONS (ON THE SAFE SIDE) CONSIDERED A LIVE LOAD.

4.1.2.2 TRANSFORMERS



SLAB DESIGN :

$$p = 1.3 \cdot 35 / 1.3 \cdot 2 = 17.5\ kN/m^2$$

BEAM DESIGN :

(THE FOLLOWING LOADS, SURFACE LOAD p, LINE LOAD q, AND POINT LOAD, ARE USED TO FIND REACTIONS ON BEAMS.

SLAB S141 :

$$p = \frac{37.3 \cdot 5 \cdot 1.3 + 2 \cdot 1.3 \cdot 35 \cdot 1.33}{42.51} = 8.6\ kN/m^2$$

B 1241 , LINE LOAD

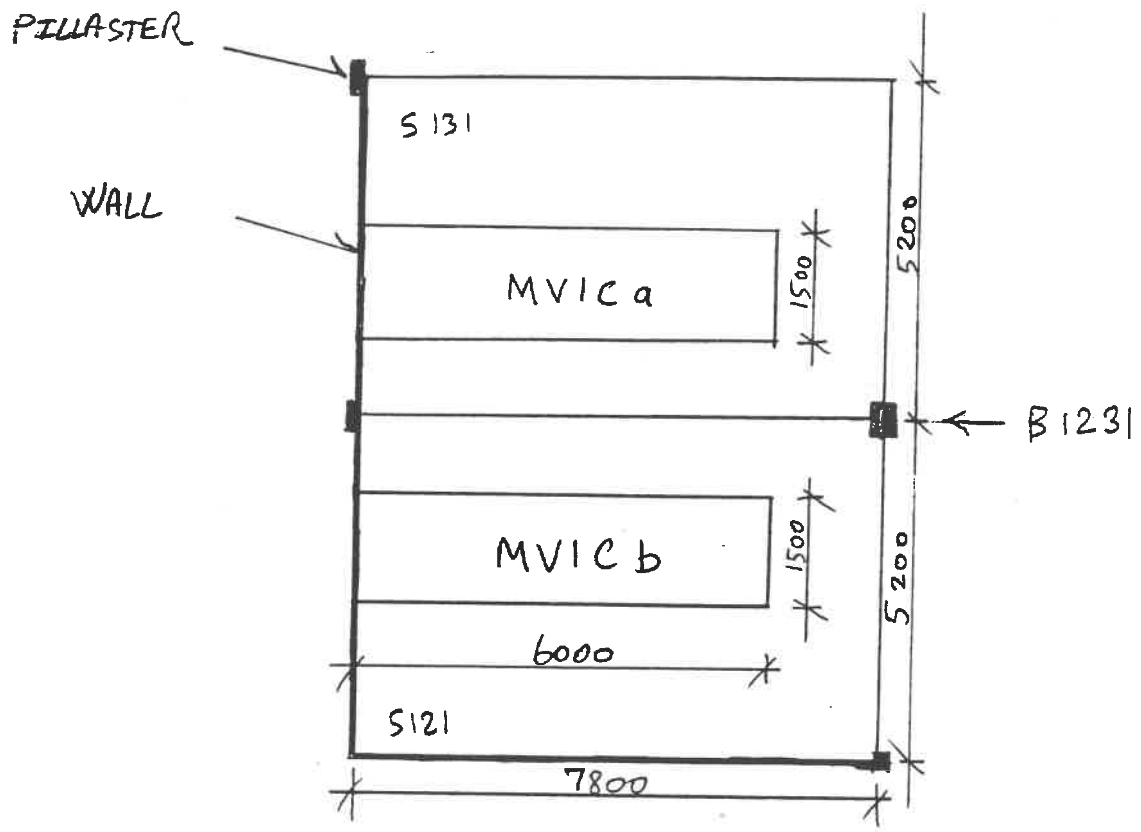
$$q = \frac{1.3 \cdot 35 \cdot 2 - 5 \cdot 1.3 \cdot 3.8 \cdot 1.3}{7.8} = 7.6\ kN/m$$

$$\sim 9.0\ kN/m$$

B1122, B1132, POINT LOADS

$1.3 \cdot 35 - 1.3 \cdot 5 \cdot 1.3 \cdot 2 = \underline{29\ kN}$

4.1.2.3 MVIC a+b, MVID a+b



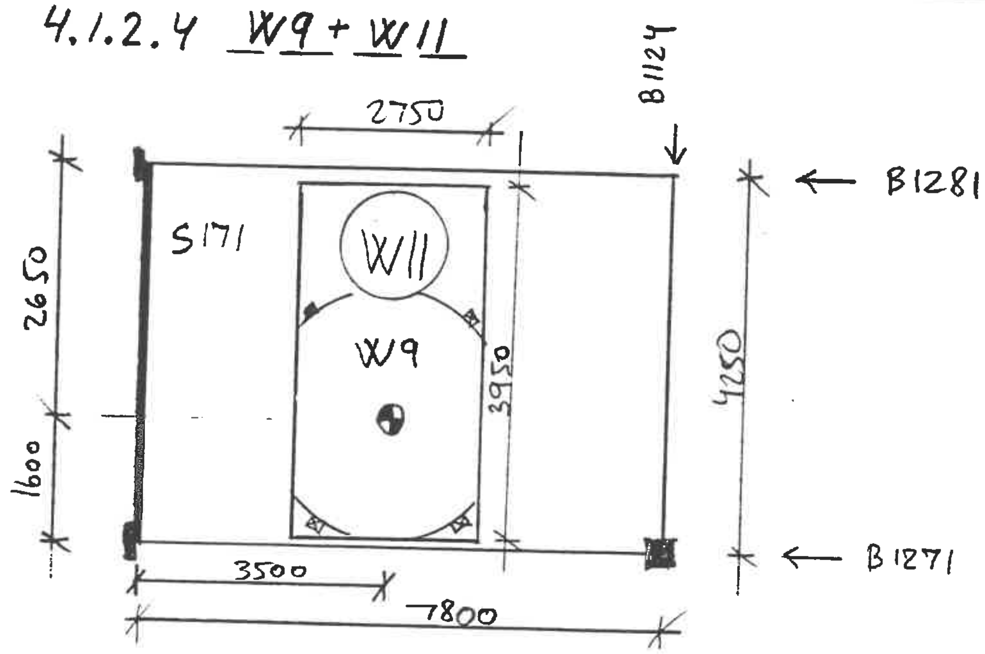
SLAB DESIGN:

$$p = \frac{72 \cdot 1.3}{6 \cdot 1.5} = 10.4 \ kN/m^2$$

BEAM DESIGN:

$$p = \qquad = 10.4 \ kN/m^2$$

4.1.2.4 W9 + W11



SLAB DESIGN :

W 9, 4 SUPPORT POINTS $1.3 \cdot 700/4$ = 228 kN EACH.

PUNCHING SHEAR IS NOT A PROBLEM.

$$P = \frac{1.3 \cdot 700}{2.75 \cdot 3} = 110\ kN/m^2$$

BEAM DESIGN :

B1271, POINT LOAD FROM W9

$$1.3 \cdot 700 \cdot \frac{3}{4} \cdot \left(\frac{2650}{4250}\right) = 426\ kN$$

B1281, POINT LOAD FROM W9 + W11

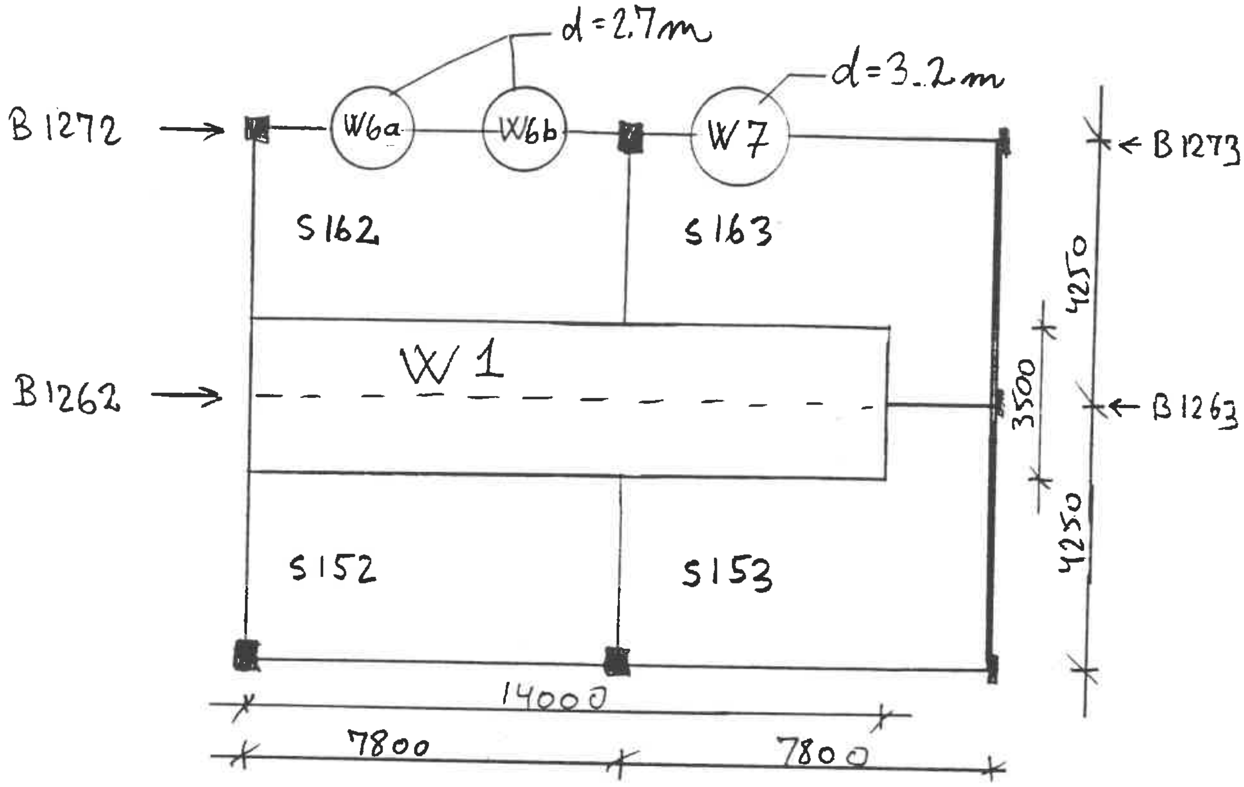
$$1.3 \cdot 700 \cdot \frac{3}{4} \cdot \left(\frac{1600}{4250}\right) + 1.3 \cdot 39 = 308\ kN$$

B1124, POINT LOAD

$$1.3 \cdot 700 \cdot \frac{1}{4} \cdot \frac{1}{2} = 114\ kN$$

$$p = \frac{(7.8 \cdot 4.25 - 2.75 \cdot 3.95) \cdot 13}{7.8 \cdot 4.25} = 8.7\ kN/m^2$$

4.1.2.5 W1



SLAB DESIGN :

LOAD FROM W1 $p = 1.3 \cdot 1304 / 14 \cdot 3.5 = 35 \ kN/m^2$

LOAD FROM W6a, W6b $p = 1.3 \cdot 404 / 5.7 = 92 \ kN/m^2$

PUNCHING SHEAR IS NOT A PROBLEM.

BEAM DESIGN :

B1272, POINT LOAD $2 \times (525 - 1.3 \cdot 10 \cdot 5.7) = 2 \times 450 \ kN$

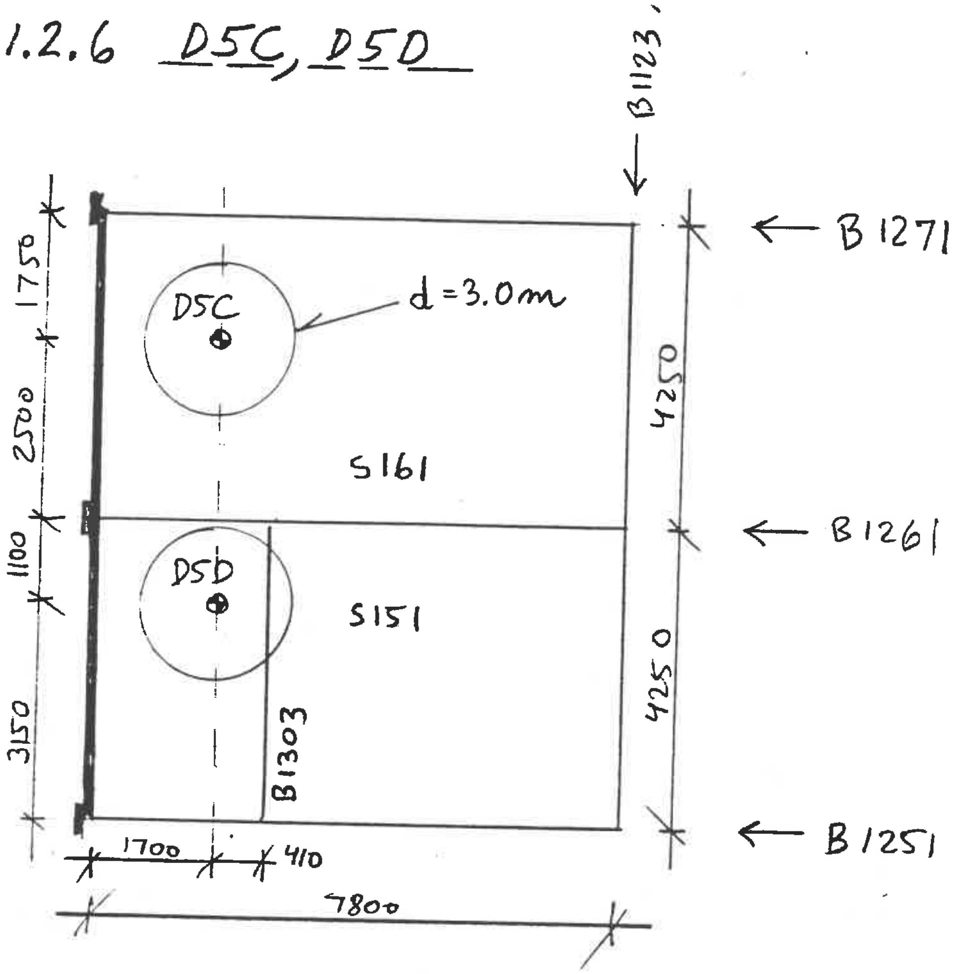
B1273, POINT LOAD $(481 - 1.3 \cdot 10 \cdot 8.04) = 376 \ kN$

B1262 + B1263, LINE LOAD

$$q = \frac{1.3 \cdot 1304 - 14 \cdot 3.5 \cdot 10 \cdot 1.3}{14} = 76 \ kN/m$$

$$p = 1.3 \cdot 10 = 13.0 \ kN/m^2$$

4.1.2.6 D5C, D5D



SLAB DESIGN:

4 SUPPORT POINTS $\frac{1.3 \cdot 290}{4}$ = 94 kN EACH

PUNCHING SHEAR IS NOT A PROBLEM.

$$p = \frac{1.3 \cdot 290}{7.07} = 53 \text{ kN/m}^2$$

BEAM DESIGN:

B1271, POINT LOAD

$$(1.3 \cdot 290 - 7.07 \cdot 13) \cdot \frac{2500}{4250} = 168 \text{ kN}$$

B1261, POINT LOAD

$$(1.3 \cdot 290 - 7.07 \cdot 13) \cdot \frac{1750}{4250} + \frac{1}{6}(1.3 \cdot 290 - 7.07 \cdot 13)$$

$$= 165 \text{ kN}$$

B1303, POINT LOAD

$$\frac{5}{6} \cdot \frac{1700}{2110} \cdot (1.3 \cdot 290 - 7.07 \cdot 13) = \underline{191 \text{ kN}}$$

$$P = 1.3 \cdot 10 = \underline{13 \text{ kN/m}^2}$$

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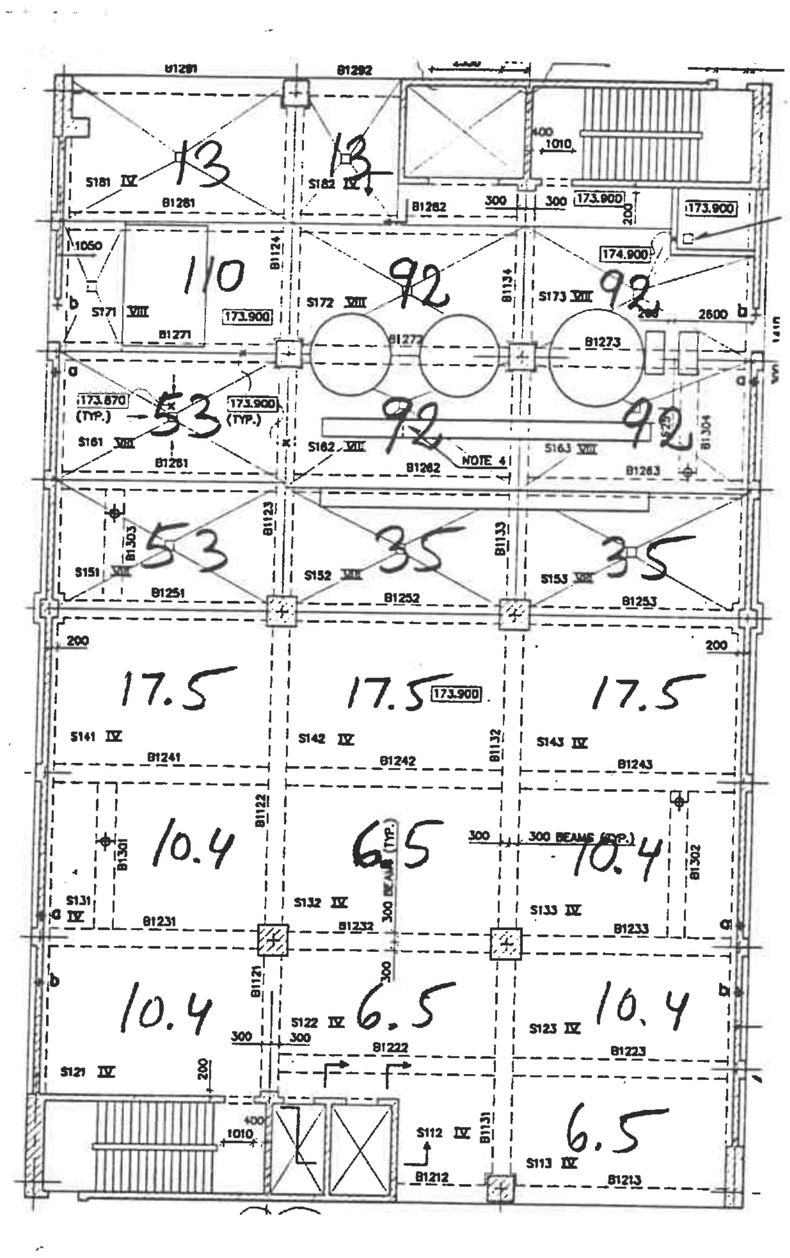
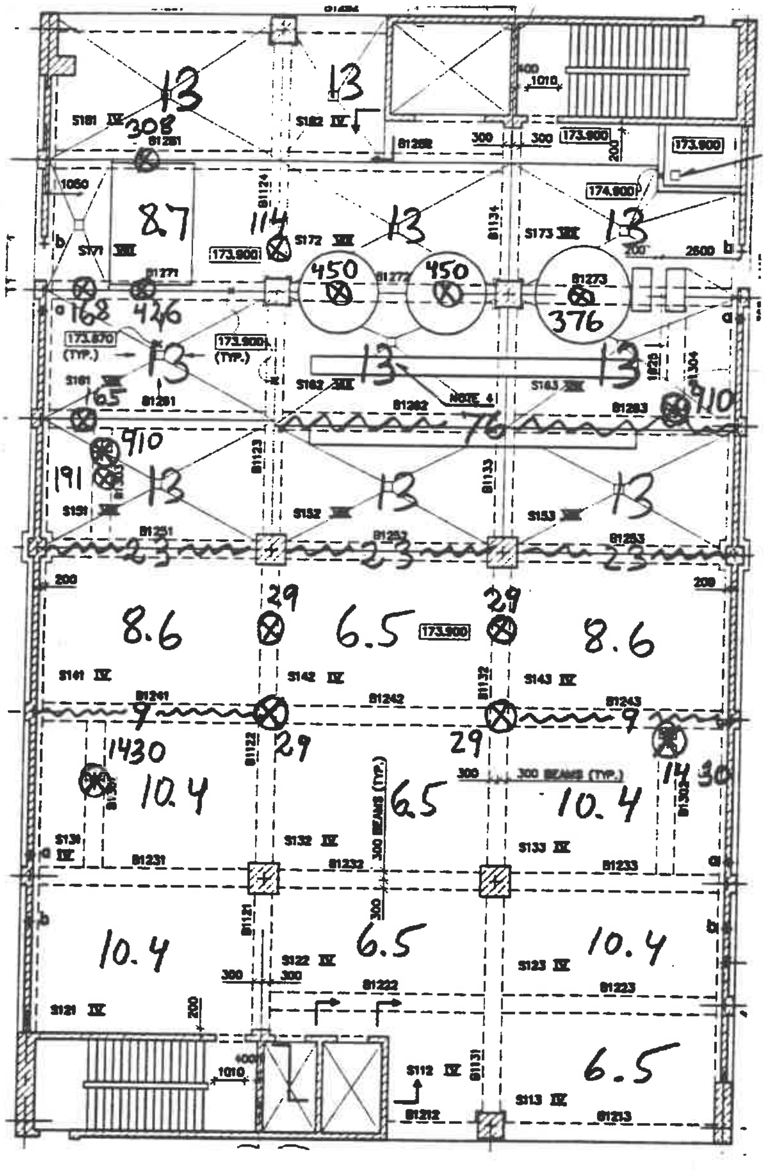
4.1.2.7 LIVE LOADS USED IN SLAB DESIGN



(UNITS kN/m^2)

4.1.2.8 LIVE LOADS USED IN BEAM DESIGN

(THESE LOADS ARE USED TO FIND REACTIONS ON BEAMS)



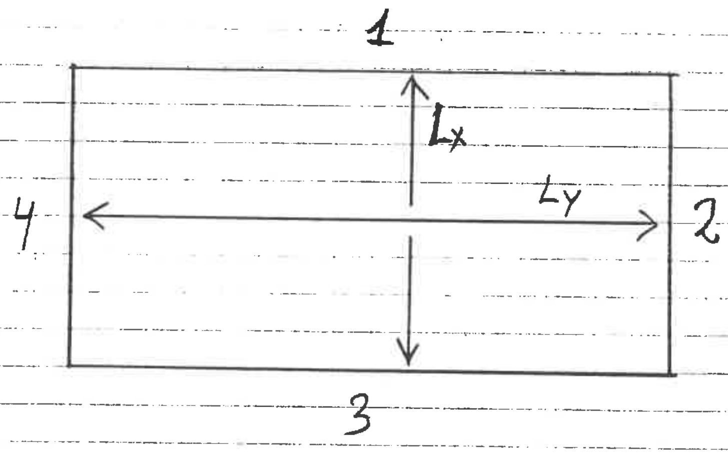
⊗ POINT LOAD (kN)

〰 LINE LOAD (kN/m)

SURFACE LOAD (kN/m^2)

4.1.3 SLABS

SIDE NUMBERS AND SIDE LENGTHS USED IN SPREAD-SHEETS ARE SHOWN BELOW:



FLSm, FGD-PLANT, POLANIEC POWER STATION
RECTANGULAR SLAB
LEVEL NO. 1
SLAB NO. S141

SHEET D

SLAB SPANNING IN TWO DIRECTIONS
DS411 METHOD [1]

GEOMETRY				
Short side, l_x	=		=	5450 mm
Long side, l_y	=		=	7800 mm
h	=		=	200 mm
h_ef	=		=	151 mm
DEGREE OF RESTRAINT AT SUPPORTS				
Long side, i_1	=		=	0,5
Short side, i_2	=		=	0,5
Long side, i_3	=		=	0,5
Short side, i_4	=		=	0
REINFORCEMENT AT BOTTOM				
Parallel with short side :		Ø=	16 mm @	200 mm
Parallel with long side :		Ø=	16 mm @	200 mm
A_sx	=	(perpendicular to short side)	=	1.005 mm^2
A_sy	=	(perpendicular to long side)	=	1.005 mm^2
MATERIALS (design values)				
f_c,d	=		=	17,1 MPa
f_t,d	=		=	1,15 MPa
f_y,d	=		=	350 MPa
E_0,k	=		=	6.400 MPa
LOADS (design loads)				
Dead load, g_1	=	h*25/1000 •/./		5,50 kN/m2
Screed, g_2	=		=	0,00 kN/m2
Permanent action, g	=		=	5,50 kN/m2
Imposed action, q	=		=	17,50 kN/m2
of which		50 % is considered as fixed action		
Total action, g + q	=	Permanent action+ imposed action	=	23,00 kN/m2
Fixed action	=	Permanent action + part of imposed action	=	14,25 kN/m2
RECOMMENDED THICKENESS [2, Pg. 198]				
g + p < 5 kN/m^2	:	h > l_x / 40	=	136 mm
g + p > 5 kN/m^2	:	h > (l_x * (g+p)/5))^0,333) / 40	=	227 mm
ALLOWABEL DEGREE OF RESTRAINT				
i_max	=		=	0,50
or				
i_max	=	0,64/(0,36+q/g)	=	0,66
where	:	g is uniformly distributed fixed action q is uniformly distributed free action		

LOAD BEARING CAPACITIES

PERPENDICULAR TO SHORT SIDE, m_x:

omega	=	(A_s,x*f_y,d)/(b*h_ef*f_c,d)		
my	=	(1-½*omega)*omega	=	0,1363
h_int_x	=	(1-omega/2)*h_ef	=	0,1270
m_x	=	my * b * h_ef^2 * f_c,d	=	140,7 mm
			=	49,51 kNm/m

PERPENDICULAR TO LONG SIDE, m_y:

omega	=	(A_s,y*f_y,d)/(b*h_ef*f_c,d)		
my	=	(1-½*omega)*omega	=	0,1363
h_int_y	=	(1-omega/2)*h_ef	=	0,1270
m_y	=	my * b * h_ef^2 * f_c,d	=	140,7 mm
			=	49,51 kNm/m
m_x/m_y	=			
l_y^2/l_x^2	=		=	1,00
m_1	=	i_1 * m_x	=	2,05
m_3	=	i_3 * m_x	=	24,76 kNm/m
m_2	=	i_2 * m_y	=	24,76 kNm/m
m_4	=	i_4 * m_y	=	24,76 kNm/m
			=	0,00 kNm/m

LOAD BEARING CAPACITY

m_x,0	=	m_x + ½(m_1 + m_3) = m_x + ½(i_1*m_x + i_3 * m_x)	=	74,27 kNm/m
m_y,0	=	m_y + ½(m_2 + m_4) = m_y + ½(i_2*m_y + i_4 * m_y)	=	61,89 kNm/m
p	=	2/(l_x*l_y) * ((1+4*l_y/l_x)*m_x,0 + (1+4*l_x/l_y)*m_y;0))	=	34,55 kN/m2
		>g+q	=	23,00 kN/m2
		Load bearing capacity OK		
"Safety"	=	p/(g+q)	=	1,50

REACTIONS

r_1 (long side)	=	+½*(g+q)*l_x	=	62,675	
		- 4*m_y,0*l_x/l_y^2 *(g+p)/q	=	-14,76	
		+ (m_1-m_3)/l_x * (g+p)/q	=	0 =	47,91 kN/m
r_3 (long side)	=	+½*(g+q)*l_x	=	62,675	
		- 4*m_y,0*l_x/l_y^2 *(g+p)/q	=	-14,76	
		- (m_1-m_3)/l_x * (g+p)/q	=	0 =	47,91 kN/m
r_2 (short side)	=	+½*(g+q)*l_y	=	89,7	
		- 4*m_x,0*l_y/l_x^2 *(g+p)/q	=	-51,94	
		+ (m_2-m_4)/l_x * (g+p)/q	=	2,113 =	39,88 kN/m
r_4 (short side)	=	+½*(g+q)*l_y	=	89,7	
		- 4*m_x,0*l_y/l_x^2 *(g+p)/q	=	-51,94	
		- (m_2-m_4)/l_x * (g+p)/q	=	-2,113 =	35,65 kN/m
F (corner reaction)	=	½*(m_x,0 + m_y,0) * (g+q)/p		=	45,32 kN

SHEAR

tau_1	=	r_1 / (b * h_int_x)		
tau_3	=	r_3 / (b * h_int_x)	=	0,34 Mpa
tau_2	=	r_2 / (b * h_int_y)	=	0,34 Mpa
tau_4	=	r_4 / (b * h_int_y)	=	0,28 Mpa
tau_max	=	0,7 * f_td	=	0,25 Mpa
			=	0,81 Mpa
		Shear bearing capacity OK		

VERTICAL PROJECTION

Permanent action	=	+g *l_x*l_y		
Imposed action	=	+q*l_x*l_y	=	233,81 kN
Line reactions	=	-(r_1 + r_3)*l_y - (r_2 +r_4)*l_x	=	743,93 kN
Corner reactions	=	+4*F	=	-1159,03 kN
Total	=		=	181,30 kN
			=	0,00 kN

ISOTROPIC SLAB [2, Pg. 122]

l_x,r	=	2 * l_x / (sqrt(1+i_1) + (sqrt(1+i_3))	=	4.450 m
l_y,r	=	2 * l_y / (sqrt(1+i_2) + (sqrt(1+i_4))	=	7.012 m
m_f / p	=	l_x.r*l_y,r / 8 / (1 + l_x,r/l_y,r + l_y,r/l_x,r)	=	1,215 m^2
m_x / p	=		=	1,433 m^2
m_y / p	=		=	1,433 m^2
m_f	=	(m / p) * (q + g)	=	27,94 kNm/m
m_f,req	=	1,3 *m_f	=	36,33 kNm/m
"Safety"	=	m_x / m_f,req	=	1,36
"Safety"	=	m_y / m_f, req	=	1,36

DEFLECTION [3] permanent action , g

I	=	b * h^3 / 12	=	666.667 mm^4 /mm
u	=	m _f * l_x^2 / (8 * E_o,k * I)*(g/(g+q))	=	5,81 mm
l_x / u	=		=	937

ISOTROPIC SLAB
Yield line ~45 gr.

m_f	=		=	27,60 kNm/m

LITERATURE

[1] DS 411, DANISH STANDARD
CODE OF PRACTICE FOR THE STRUCTURAL USE OF CONCRETE, MARCH 1984.

[2] TEKNISK STÅBI, 15. EDITION, 1986.

[3] K. W. JOHANSEN: YIELD-LINE FORMULAE FOR SLABS
CEMENT AND CONCRETE ASSOCIATION, 1972.

FLSm, FGD-PLANT, POLANIEC POWER STATION
RECTANGULAR SLAB
LEVEL NO. 1
SLAB NO. S171

SHEET D

SLAB SPANNING IN TWO DIRECTIONS
DS411 METHOD [1]

GEOMETRY				
Short side, l_x	=		=	4250 mm
Long side, l_y	=		=	7800 mm
h	=		=	350 mm
h_ef	=		=	301 mm
DEGREE OF RESTRAINT AT SUPPORTS				
Long side, i_1	=		=	0,5
Short side, i_2	=		=	0,5
Long side, i_3	=		=	0,5
Short side, i_4	=		=	0
REINFORCEMENT AT BOTTOM				
Parallel with short side :		Ø=	16 mm @	150 mm
Parallel with long side :		Ø=	16 mm @	150 mm
A_sx	=	(perpendicular to short side)	=	1.340 mm^2
A_sy	=	(perpendicular to long side)	=	1.340 mm^2
MATERIALS (design values)				
f_c,d	=		=	17,1 MPa
f_t,d	=		=	1,15 MPa
f_y,d	=		=	350 MPa
E_0,k	=		=	6.400 MPa
LOADS (design loads)				
Dead load, g_1	=	(h*25/1000)*1,1)		9,63 kN/m2
Screed, g_2	=		=	1,00 kN/m2
Permanent action, g	=		=	10,63 kN/m2
Imposed action, q	=		=	110,00 kN/m2
of which		50 % is considered as fixed action		
Total action, g + q	=	Permanent action+ imposed action	=	120,63 kN/m2
Fixed action	=	Permanent action + part of imposed action	=	65,63 kN/m2
RECOMMENDED THICKENESS [2, Pg. 198]				
g + p < 5 kN/m^2	:	h > l_x / 40	=	106 mm
g + p > 5 kN/m^2	:	h > (l_x * (g+p)/5))^0,333) / 40	=	307 mm
ALLOWABEL DEGREE OF RESTRAINT				
i_max	=		=	0,50
or				
i_max	=	0,64/(0,36+q/g)	=	0,53
where	:	g is uniformly distributed fixed action q is uniformly distributed free action		

LOAD BEARING CAPACITIES

PERPENDICULAR TO SHORT SIDE, m_x:

omega	=	(A_s,x*f_y,d)/(b*h_ef*f_c,d)		
my	=	(1-½*omega)*omega	=	0,0911
h_int_x	=	(1-omega/2)*h_ef	=	0,0870
m_x	=	my * b * h_ef^2 * f_c,d	=	287,3 mm
			=	134,78 kNm/m

PERPENDICULAR TO LONG SIDE, m_y:

omega	=	(A_s,y*f_y,d)/(b*h_ef*f_c,d)		
my	=	(1-½*omega)*omega	=	0,0911
h_int_y	=	(1-omega/2)*h_ef	=	0,0870
m_y	=	my * b * h_ef^2 * f_c,d	=	287,3 mm
			=	134,78 kNm/m
m_x/m_y	=			
l_y^2/l_x^2	=		=	1,00
m_1	=	i_1 * m_x	=	3,37
m_3	=	i_3 * m_x	=	67,39 kNm/m
m_2	=	i_2 * m_y	=	67,39 kNm/m
m_4	=	i_4 * m_y	=	67,39 kNm/m
			=	0,00 kNm/m

LOAD BEARING CAPACITY

m_x,0	=	m_x + ½(m_1 + m_3) = m_x + ½(i_1*m_x + i_3 * m_x)	=	202,17 kNm/m
m_y,0	=	m_y + ½(m_2 + m_4) = m_y + ½(i_2*m_y + i_4 * m_y)	=	168,47 kNm/m
p	=	2/(l_x*l_y) * ((1+4*l_y/l_x)*m_x,0 + (1+4*l_x/l_y)*m_y;0))	=	134,05 kN/m2
		>g+q	=	120,63 kN/m2
"Safety"	=	p/(g+q)		Load bearing capacity OK
			=	1,11

REACTIONS

r_1 (long side)	=	+½*(g+q)*l_x	=	256,33		
		- 4*m_y,0*l_x/l_y^2 *(g+p)/q	=	-42,36		
		+ (m_1-m_3)/l_x * (g+p)/q	=	0	=	213,97 kN/m
r_3 (long side)	=	+½*(g+q)*l_x	=	256,33		
		- 4*m_y,0*l_x/l_y^2 *(g+p)/q	=	-42,36		
		- (m_1-m_3)/l_x * (g+p)/q	=	0	=	213,97 kN/m
r_2 (short side)	=	+½*(g+q)*l_y	=	470,44		
		- 4*m_x,0*l_y/l_x^2 *(g+p)/q	=	-314,2		
		+ (m_2-m_4)/l_x * (g+p)/q	=	7,7741	=	163,99 kN/m
r_4 (short side)	=	+½*(g+q)*l_y	=	470,44		
		- 4*m_x,0*l_y/l_x^2 *(g+p)/q	=	-314,2		
		- (m_2-m_4)/l_x * (g+p)/q	=	-7,774	=	148,44 kN/m
F (corner reaction)	=	½*(m_x,0 + m_y,0) * (g+q)/p			=	166,75 kN

SHEAR

tau_1	=	r_1 / (b * h_int_x)		
tau_3	=	r_3 / (b * h_int_x)	=	0,74 Mpa
tau_2	=	r_2 / (b * h_int_y)	=	0,74 Mpa
tau_4	=	r_4 / (b * h_int_y)	=	0,57 Mpa
tau_max	=	0,7 * f_td	=	0,52 Mpa
			=	0,81 Mpa

Shear bearing capacity OK

VERTICAL PROJECTION

Permanent action	=	+g *l_x*l_y		
Imposed action	=	+q*l_x*l_y	=	352,22 kN
Line reactions	=	-(r_1 + r_3)*l_y - (r_2 +r_4)*l_x	=	3646,50 kN
Corner reactions	=	+4*F	=	-4665,73 kN
Total	=		=	667,01 kN
			=	0,00 kN

ISOTROPIC SLAB [2, Pg. 122]

l_x,r	=	2 * l_x / (sqrt(1+i_1) + (sqrt(1+i_3))	=	3.470 m
l_y,r	=	2 * l_y / (sqrt(1+i_2) + (sqrt(1+i_4))	=	7.012 m
m_f / p	=	l_x.r*l_y,r / 8 / (1 + l_x,r/l_y,r + l_y,r/l_x,r)	=	0,865 m^2
m_x / p	=		=	1,005 m^2
m_y / p	=		=	1,005 m^2
m_f	=	(m / p) * (q + g)	=	104,36 kNm/m
m_f,req	=	1,3 *m_f	=	135,67 kNm/m
"Safety"	=	m_x / m_f,req	=	0,99
"Safety"	=	m_y / m_f, req	=	0,99

DEFLECTION [3] permanent action , g

I	=	b * h^3 / 12	=	3.572.917 mm^4 /mm
u	=	m _f * l_x^2 / (8 * E_o,k * I)*(g/(g+q))	=	0,91 mm
l_x / u	=		=	4.682

ISOTROPIC SLAB
Yield line ~45 gr.

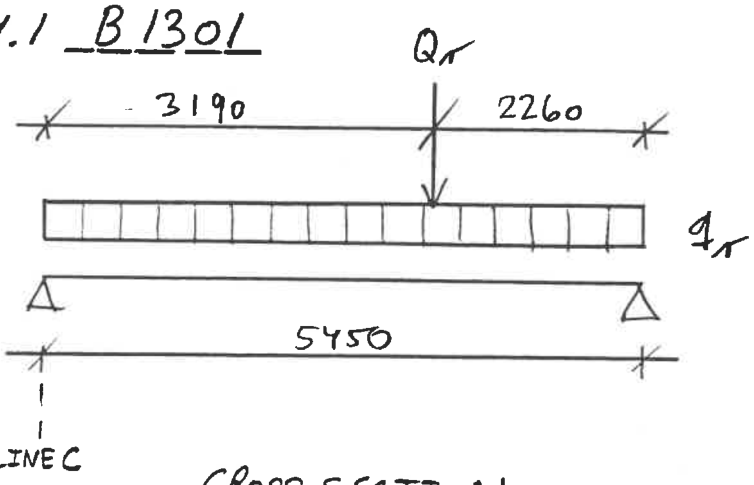
m_f	=		=	102,19 kNm/m

LITERATURE

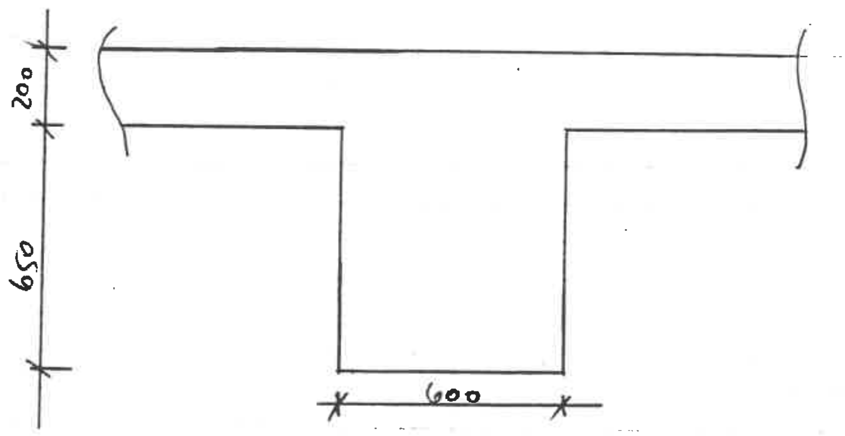
[1] DS 411, DANISH STANDARD
CODE OF PRACTICE FOR THE STRUCTURAL USE OF CONCRETE, MARCH 1984.
[2] TEKNISK STÅBI, 15. EDITION, 1986.
[3] K. W. JOHANSEN: YIELD-LINE FORMULAE FOR SLABS
CEMENT AND CONCRETE ASSOCIATION, 1972.

4.1.4 TERTIARY BEAMS

4.1.4.1 B1301



CROSS SECTION



DEAD LOAD FROM BEAM:

0.85 · 0.6 · 25 · 1.1 = 14 kN/m

LINE LOAD FROM ADJACENT SLABS:

DEAD LOAD ~ 11 kN/m

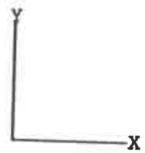
LIVE LOAD ~ 21 kN/m

35 kN/m

Q_r : LIVE LOAD = 1430 kN

q_r :	TOTAL DEAD LOAD	= 25 kN/m
	TOTAL LIVE LOAD	= 21 kN/m
		46 kN/m
Q_r :	TOTAL LIVE LOAD	= 1430 kN

ORIENTATION

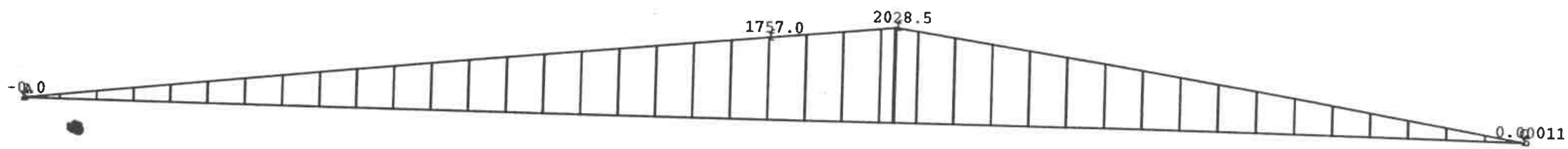


BENDING REINFORCEMENT 14∅32, BOTTOM

HORIZONTAL SCALE = .5423 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0



MOMENT DISTRIBUTION - TERTIARY BEAM B1301

4.1 - 21

T-SHAPED BEAM
TERTIARY BEAM
1. LEVEL AT MIDSPAN

SHEET A

GEOMETRY					
Height, h	=			=	850 mm
Width top., b_t	=			=	1.500 mm
Width bot., b_b	=			=	600 mm
Flange thick., t	=			=	200 mm
Cover layer, c	=			=	89 mm
Eff. height, h_0	=	h -c		=	761 mm
Length, l	=			=	5,45 m
REINFORCEMENT					
No. of bars	=			=	14 pcs. } BOTTOM
Bar diameter	=			=	32 mm }
F_a	=			=	11259 mm^2
fi (T-beam)	=	F_a / (h * b_f) = F_a / (h * (b_b + 2*t))	>fi_min OK	=	1,32 %
fi (rect. beam)	=	F_a / (h * b_b)	>fi_min OK	=	2,21 %
MATERIALS					
R_b	=			=	17,1 MPa B30
R_bk	=			=	22,2 MPa
R_bzk	=			=	1,7 MPa
R_bz	=			=	1,2 MPa
R_a	=			=	350 MPa
R_ak	=			=	410 MPa
n_short time	=			=	6,48
n_long time	=			=	33,00
E-ak	=			=	210.000 MPa
E_b	=			=	32.400 MPa
fi_min	=	0,45 *R_bzk /R_ak		=	0,19 %
LOADS					
M_ult	=			=	2029 kNm
M_k (short time)	=	(50% live load, characteristic load)		=	670 kNm
M_d (long time)	=	(50% live load + 100% dead load, characteristic load)		=	1015 kNm
kap_f	=	1+0,5*(M_k/(M_k+M_d))		=	1,20
M_c	=	M_k+kap_f*M_d		=	1.887 kNm
ULTIMATE LOAD BEARING CAPACITY		acc. to ds 411			
omega_bal	=			=	0,50
omega	=	(F_a*R_a)/(b_t*h_0*R_b)	< omega_bal OK	=	0,2019
my	=	(1-½*omega)*omega		=	0,1815
beta	=	1,25 * omega		=	0,2524
h_c	=	beta * h_0	<1,33 * t OK	=	192,0 mm
M_u,d (+)	=	my * b * h_0^2 * R_b	>M_ult	=	2.696 kNm
"Safety"	=	M_u,d(+) / M_ult		Load bearing capacity OK =	1,33
ULTIMATE LOAD BEARING CAPACITY		acc. to polish standard			
X	=	(R_a*F_a)/(b_t*R_b)		=	153,64 mm
psi	=	X/h_0		=	0,20 <psi_gr, OK
psi_gr	=			=	0,50
M_ud	=	R_a*F_a*(h_0 - 0.5*X)	>M_ult	=	2696 KNm
"Safety"	=	M_u,d(+) / M_ult		Load bearing capacity OK =	1,33

4.1-22

METHODE B:
ELASTIC ANALYSIS

SHORT TIME		DS 411		
fi	=	F_a / b_t /h_0	=	0,0099
n * fi	=		=	0,064
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)	=	0,299
y_0	=	beta * h_0	=	228 mm
		<1,25 * t, OK		
fi_b	=	beta/6*(3-beta)	=	0,135
gamma	=	(1 - beta) / beta	=	2,341
sigma_c, max	=	M_k / (fi_b*b_t*h_0^2)	=	5,7 MPa
sigma_a, max	=	n * gamma * sigma_c,max	=	87 MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)	=	238 mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5	=	0,07 mm
				(CRACK WIDTH)
u_0	=	n * sigma_a,max * l^2 / (10 * y_0 * E_ak)	=	2,3 mm
				(DEFLECTION)
l / u_0	=		=	2.365

LONG TIME		DS 411		
fi	=	F_a / b_t /h_0	=	0,0099
n * fi	=		=	0,326
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)	=	0,545
y_0	=	beta * h_0	=	414
		<1,25 * t, OK		
fi_b	=	beta/6*(3-beta)	=	0,223
rho	=	beta*fi_b	=	0,121
I_zt	=	rho*b_t*h_0^3	=	8,02E+10 mm^4 ← I_{zt}
gamma	=	(1 - beta) / beta	=	0,836
sigma_c, max	=	M_d / (fi_b*b_t*h_0^2)	=	5,2 MPa
sigma_a, max	=	n * gamma * sigma_c,max	=	145 MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)	=	238 mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5	=	0,11 mm
u_0	=	n * sigma_c,max * l^2 / (10 * y_0 * E_ak)	=	5,9 mm
l / u_0	=		=	923

Crackwidth acc. to Polish standard

gam_a	=		=	0,00
gam_b	=	(b_t-b_b)*t/(b_b*h_0)	=	0,394
L	=	M_c/(R_bk*b_b*h_0^2)	=	0,24
G	=	gam_b*(1-t/(2*h_0))+gam_a*(1-a/h_0)	=	0,342
my_a	=	F_a/(b_b*h_0)	=	0,025
psi_f	=	1/(1,8+(1+5*(L+G))/(10*n*my_a))	=	0,235
		< t'/h_0 , OK !		
Z_f	=	FORMULA (Z5-9)	=	665 mm
sigma_a	=	M_c/(Z_f*F__a)	=	252 MPa

n	=	E_ak/E_b	=	6,48
delta_1	=	(b_t-b_b)*t/(b_b*h)	=	0,35
M_fp	=	[0,292+1,5*n/(b_b*h)*(F_a+0,1*F_ac)+0,15*delta_1]*b_b*h^2*R_bzk	=	420 kNm
psi_a	=	1,3-0,8*M_fp/M_c	=	1,000
K_1	=	M_fp/(Z_f*n*F_a*R_bzk) - 2	=	3,00
l_f	=	K_1*n*F_a/(sum u_a)*n_f	=	109 mm
a_sr	=	psi_a*(sigma_a/E_ak)*l_f	=	0,131
k_f	=		=	1,597
a_f	=	k_f*a_sr	=	0,209 mm
		<0,3 mm, OK		

CALCULATION OF DEFLECTION

TRANSFORMED MOMENT OF INERTIA :

$I_{zt} = 8.02 \cdot 10^{10}$ mm^4 (REF. SPREAD-SHEET CALC.)

LONG ACTING LOAD: (DEAD LOAD +50% LIVE LOAD, CHARACTERISTIC VALUES)

$\frac{1}{1.2} \cdot 60\%$ = 50% OF TOTAL DESIGN LOAD

$E = \frac{210000}{33} = 6400$ N/mm^2 (E-MODULUS REDUCED DUE TO CREEP)

SHORT ACTING LOAD: (50% LIVE LOAD, CHARACTERISTIC VALUES)

$\frac{1}{1.2} \cdot 40\%$ = 33% OF TOTAL DESIGN LOAD

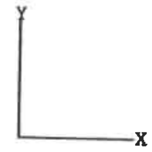
$E = \frac{210000}{6.48} = 32400$ N/mm^2

MAX DISPLACEMENT FROM LONG ACTING LOAD:

$0.5 \cdot 9.9 = \underline{\underline{5.0}}$ mm

VALUE CALCULATED WITH THE USE OF GTSTRUDL.

ORIENTATION



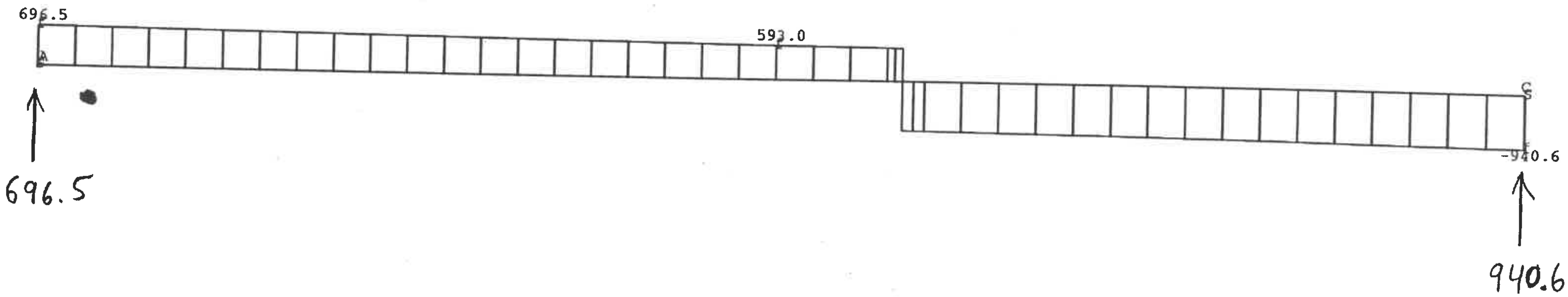
SHEAR REINFORCEMENT $\phi 16$, 4 SECTIONS

a_t = 200 mm IN THE ENTIRE BEAM LENGTH.

HORIZONTAL SCALE = .5423 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0



SHEAR FORCE DISTRIBUTION - TERTIARY BEAM B1301

4.1-25

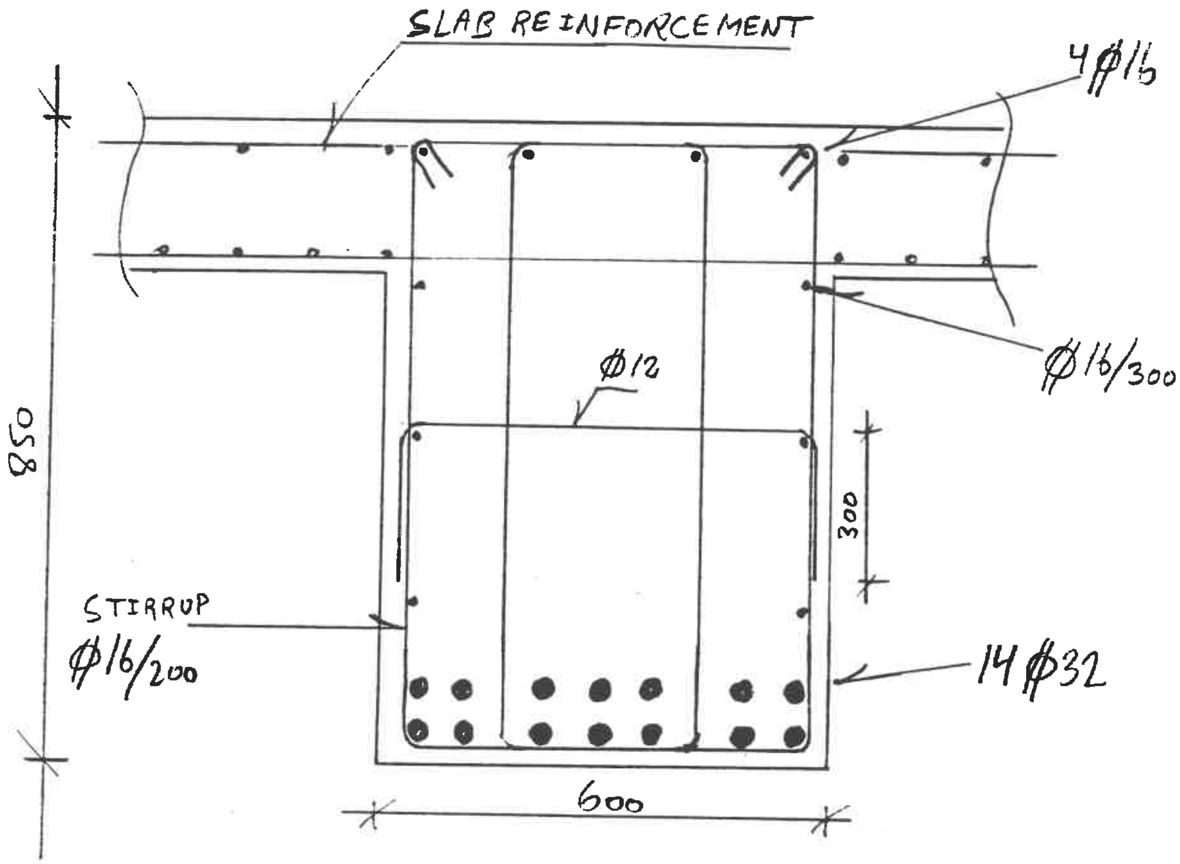
SHEAR CALCULATION acc. to polish standard

STIRRUPS				
Bar diameter, d_s			=	16 mm
No. of sections	=		=	4
F_s	=		=	804 mm^2
gam_f0	=		=	1,2
sigma_p	=	(VALUE TAKEN FROM TABLE 12 IN PN-84/B-3264)	=	387 N/mm^2
sigma_ps	=	sigma_p/sqrt(0.1*d_s)	=	306 N/mm^2
sigma_max	=	0,8*R_as**R_b*b_b*h_0/(2.4*gam_f0*Q_1)	=	646 N/mm^2
		sigma_ps < sigma_max, OK		

Q_1	=		=	940,6 kN
Q_min	=	0.75*R_bz*b_b*h_0	=	394 kN
Q_max	=	0,25*R_b*b_b*h_0	=	1952 kN
		> Q_1, OK		
q	=		=	38 kN/m
SUM_Ni	=		=	0 kN
		(SUM_Ni is sum of konc. loads between Q_1 and Q_min)		
c_0	=	(Q_1-Q_MIN-SUM_Ni)/q	=	14,389 m
		c_0 > h_0 , Q_2,Q_3 ... COULD BE GIVEN !!!		
c_01	=	(IF c_0 < h_0 THEN c_01 = c_0)	=	2,725 m
T_1	=	Q_1*c_01/h_0	=	3368 kN
n_s	=	T_1/(gam_f0*sigma_ps*F_s)	=	12
a_t	=	c_01/n_s	=	227 mm
fi_min	=	0,2*R_bzk/0,8*R_ak	=	0,105 %
a_t,min,1	=	F_s/(fi_min*b_b)	=	1271 mm
				or
a_t,min,2	=	0,7*h	=	595 mm
a_t,min	=	MIN(a_t,min,1 ; a_t,min,2)	=	595 mm
		> a_t, OK		

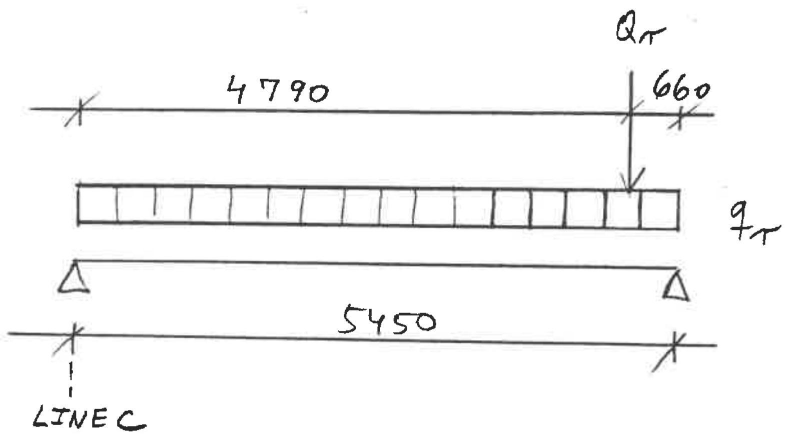
2

REINFORCEMENT AT MIDSPAN



COVER 20mm, +5/-0 mm

4.1.4.2 B 1302

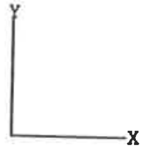


q_T : TOTAL DEAD LOAD	=	25 kN/m
TOTAL LIVE LOAD	=	21 kN/m
		46 kN/m
Q_T : TOTAL LIVE LOAD	=	1430 kN

BENDING REINFORCEMENT

10 ϕ 25, BOTTOM

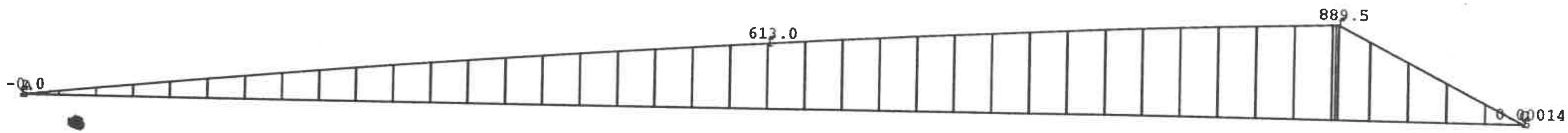
ORIENTATION



HORIZONTAL SCALE = .5423 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0



MOMENT DISTRIBUTION - TERTIARY BEAM B1302

4.1-29

T-SHAPED BEAM
TERTIARY BEAM
1. LEVEL

SHEET A

AT MIDSPAN

GEOMETRY

Height, h	=			
Width top., b_t	=		=	850 mm
Width bot., b_b	=		=	1.500 mm
Flange thick., t	=		=	600 mm
Cover layer, c	=		=	200 mm
Eff. height, h_0	=	h -c	=	80 mm
Length, l	=		=	770 mm
			=	5,45 m

REINFORCEMENT

No. of bars	=				
Bar diameter	=			=	10 pcs. } BOTTOM
F_a	=			=	25 mm }
fi (T-beam)	=	F_a / (h * b_f) = F_a / (h * (b_b + 2*t))		=	4909 mm^2
				=	0,58 %
			>fi_min OK		
fi (rect. beam)	=	F_a / (h * b_b)			
				=	0,96 %
			>fi_min OK		

MATERIALS

R_b	=			
R_bk	=		=	17,1 MPa
R_bzk	=		=	22,2 MPa
R_bz	=		=	1,7 MPa
R_a	=		=	1,2 MPa
R_ak	=		=	350 MPa
n_short time	=		=	410 MPa
n_long time	=		=	6,48
E-ak	=		=	33,00
E_b	=		=	210.000 MPa
fi_min	=	0,45 *R_bzk /R_ak	=	32.400 MPa
			=	0,19 %

LOADS

M_ult	=			
M_k (short time)	=	(50% live load, characteristic load)	=	890 kNm
M_d (long time)	=	(50% live load + 100% dead load, characteristic load)	=	294 kNm
kap_f	=	1+0,5*(M_k/(M_k+M_d))	=	445 kNm
M_c	=	M_k+kap_f*M_d	=	1,20
			=	828 kNm

ULTIMATE LOAD BEARING CAPACITY acc. to ds 411

omega_bal	=				
omega	=	(F_a*R_a)/(b_t*h_0*R_b)		=	0,50
				=	0,0870
			< omega_bal OK		
my	=	(1-½*omega)*omega			
beta	=	1,25 * omega		=	0,0832
h_c	=	beta * h_0		=	0,1087
				=	83,7 mm
			<1,33 * t OK		
M_u,d (+)	=	my * b * h_0^2 * R_b		=	1.265 kNm
"Safety"	=	M_u,d(+) / M_ult	>M_ult		Load bearing capacity OK
				=	1,42

ULTIMATE LOAD BEARING CAPACITY acc. to polish standard

X	=	(R_a*F_a)/(b_t*R_b)			
psi	=	X/h_0		=	66,98 mm
psi_gr	=			=	0,09 <psi_gr, OK
M_ud	=	R_a*F_a*(h_0 - 0.5*X)		=	0,50
				=	1265 KNm
"Safety"	=	M_u,d(+) / M_ult	>M_ult		Load bearing capacity OK
				=	1,42

4.1 - 30

METHODE B:
ELASTIC ANALYSIS

SHORT TIME		DS 411			
fi	=	F_a / b_t /h_0		=	0,0042
n * fi	=			=	0,028
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)		=	0,209
y_0	=	beta * h_0		=	161 mm
			<1,25 * t, OK		
fi_b	=	beta/6*(3-beta)		=	0,097
gamma	=	(1 - beta) / beta		=	3,790
sigma_c, max	=	M_k / (fi_b*b_t*h_0^2)		=	3,4 MPa
sigma_a, max	=	n * gamma * sigma_c,max		=	84 MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)		=	384 mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5		=	0,08 mm (CRACK WIDTH)
u_0	=	n * sigma_a,max * l^2 / (10 * y_0 * E_ak)		=	1,9 mm (DEFLECTION)
l / u_0	=			=	2.808

LONG TIME		DS 411			
fi	=	F_a / b_t /h_0		=	0,0042
n * fi	=			=	0,140
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)		=	0,408
y_0	=	beta * h_0		=	314
			<1,25 * t, OK		
fi_b	=	beta/6*(3-beta)		=	0,176
rho	=	beta*fi_b		=	0,072
I_zt	=	rho*b_t*h_0^3		=	4,92E+10 mm^4
gamma	=	(1 - beta) / beta		=	1,453
sigma_c, max	=	M_d / (fi_b*b_t*h_0^2)		=	2,8 MPa
sigma_a, max	=	n * gamma * sigma_c,max		=	136 MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)		=	384 mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5		=	0,13 mm
u_0	=	n * sigma_c,max * l^2 / (10 * y_0 * E_ak)		=	4,2 mm
l / u_0	=			=	1.290

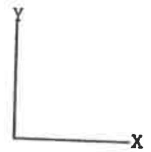
Crackwidth acc. to Polish standard

gam_a	=			=	0,00
gam_b	=	(b_t-b_b)*t/(b_b*h_0)		=	0,390
L	=	M_c/(R_bk*b_b*h_0^2)		=	0,10
G	=	gam_b*(1-t/(2*h_0))+gam_a*(1-a/h_0)		=	0,339
my_a	=	F_a/(b_b*h_0)		=	0,011
psi_f	=	1/(1,8+(1+5*(L+G))/(10*n*my_a))		=	0,154
			< t'/h_0 , OK !		
Z_f	=	FORMULA (Z5-9)		=	682 mm
sigma_a	=	M_c/(Z_f*F__a)		=	247 MPa

n	=	E_ak/E_b		=	6,48
delta_1	=	(b_t-b_b)*t/(b_b*h)		=	0,35
M_fp	=	[0,292+1,5*n/(b_b*h)*(F_a+0,1*F_ac)+0,15*delta_1]*b_b*h^2*R_bzk		=	329 kNm
psi_a	=	1,3-0,8*M_fp/M_c		=	0,982
K_1	=	M_fp/(Z_f*n*F_a*R_bzk) - 2		=	6,77
l_f	=	K_1*n*F_a/(sum u_a)*n_f		=	192 mm
a_sr	=	psi_a*(sigma_a/E_ak)*l_f		=	0,222
k_f	=			=	1,140
a_f	=	k_f*a_sr		=	0,253 mm
			<0,3 mm, OK		

SHEAR REINFORCEMENT ! ϕ12/ϕ16 ; 4 SECTIONS

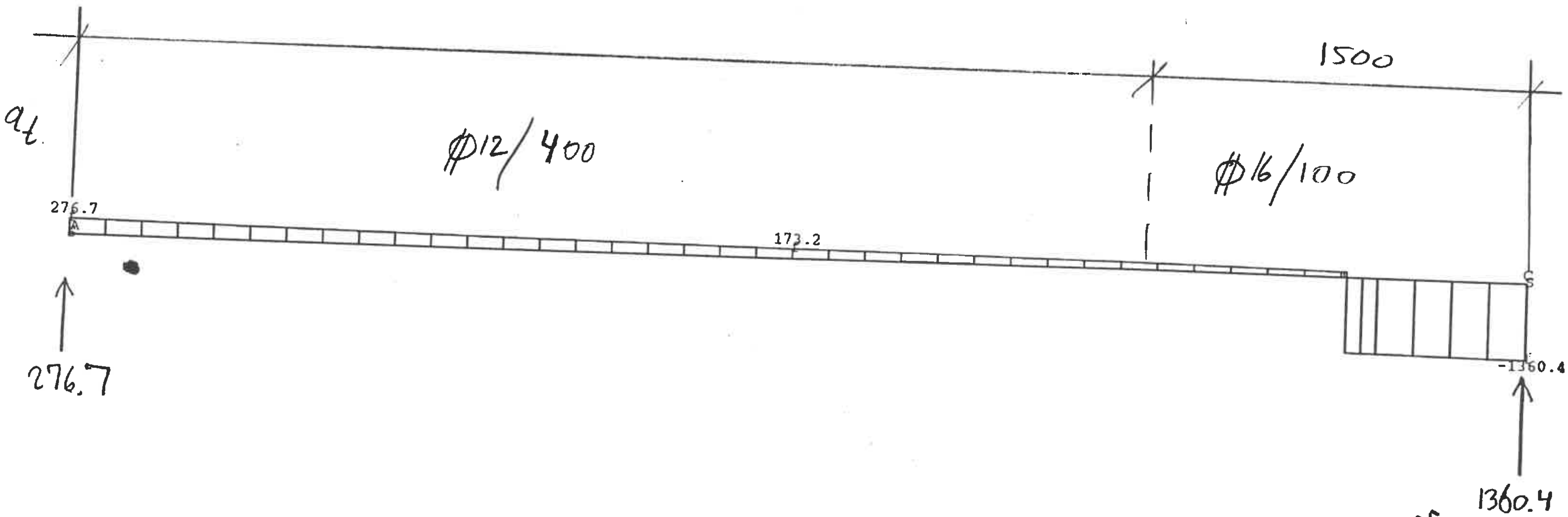
ORIENTATION



HORIZONTAL SCALE = .5423 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0



4.1-31

SHEAR FORCE DISTRIBUTION - TERTIARY BEAM B1302

SHEAR CALCULATION acc. to polish standard 4.1-32

STIRRUPS
Bar diameter, d_s
No. of sections = = 16 mm
F_s = = 4
gam_f0 = = 804 mm^2
sigma_p = = 1,2
sigma_p = (VALUE TAKEN FROM TABLE 12 IN PN-84/B-3264) = 387 N/mm^2
sigma_ps = sigma_p/sqrt(0.1*d_s) = 306 N/mm^2
sigma_max = 0,8*R_as**R_b*b_b*h_0/(2.4*gam_f0*Q_1) = 452 N/mm^2
sigma_ps < sigma_max, OK

Q_1 =
Q_min = 0.75*R_bz*b_b*h_0 = 1360,4 kN
Q_max = 0,25*R_b*b_b*h_0 = 398 kN
= 1975 kN
> Q_1, OK
q =
SUM_Ni = = 38 kN/m
= 0 kN
(SUM_Ni is sum of konc. loads between Q_1 and Q_min)
c_0 = (Q_1-Q_MIN-SUM_Ni)/q = 25,314 m
c_0 > h_0 , Q_2,Q_3 ... COULD BE GIVEN !!!
c_01 = (IF c_0 < h_0 THEN c_01 = c_0) = 0,66 m
T_1 = Q_1*c_01/h_0 = 1166 kN
n_s = T_1/(gam_f0*sigma_ps*F_s) = 4
a_t = c_01/n_s = 165 mm
fi_min = 0,2*R_bzk/0,8*R_ak = 0,105 %
a_t,min,1 = F_s/(fi_min*b_b) = 1271 mm
or
a_t,min,2 = 0,7*h = 595 mm
a_t,min = MIN(a_t,min,1 ; a_t,min,2) = 595 mm
> a_t, OK

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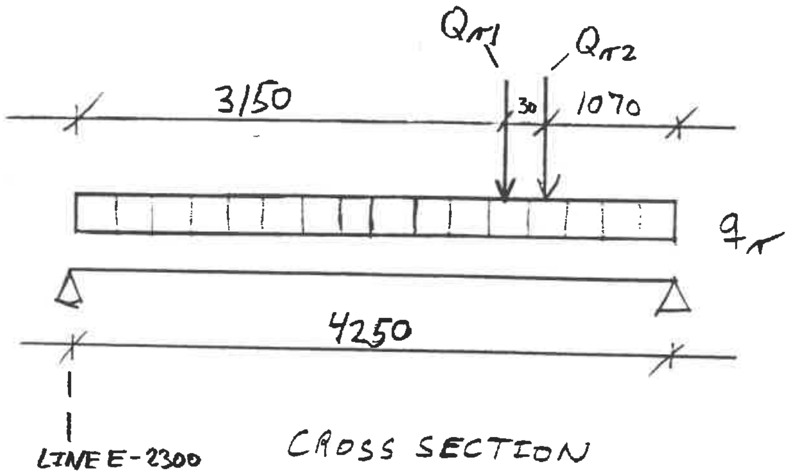
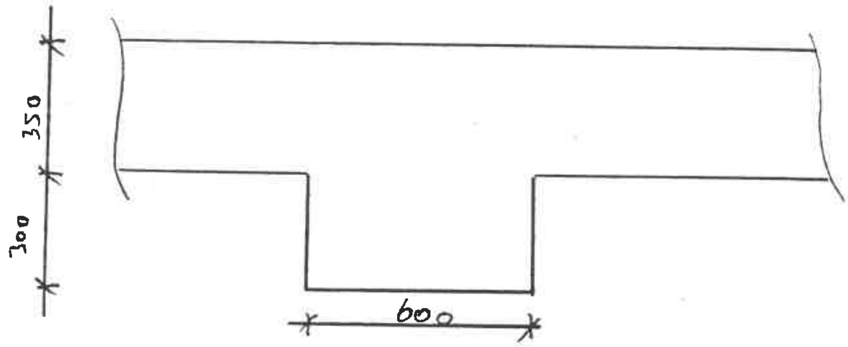
Sag / Case	Udført / Made	Godkendt / Approved	Dato / Date	Side / Page
95115	MFo	JI	96.04.12	41-33

4.1.4.3 B1303



CROSS SECTION



DEAD LOAD FROM BEAM :

$0.65 \cdot 0.6 \cdot 25 \cdot 1.1 \qquad = 10.7$ kN/m

LINE LOAD FROM ADJACENT SLABS :

DEAD LOAD $\qquad \sim 19$ kN/m

LIVE LOAD $\qquad \sim 45$ kN/m

$\qquad\qquad 64$ kN/m

Q_{T1} : LIVE LOAD $\qquad = 191$ kN

Q_{T2} : LIVE LOAD $\qquad = 910$ kN

q_T : TOTAL DEAD LOAD $\qquad = 30$ kN/m

TOTAL LIVE LOAD $\qquad = 45$ kN/m

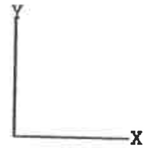
$\qquad\qquad 75$ kN/m

Q_{T1}: TOTAL LIVE LOAD $\qquad = 191$ kN

Q_{T2}: TOTAL LIVE LOAD $\qquad = 910$ kN

BENDING REINFORCEMENT 8 Ø32 BOTTOM

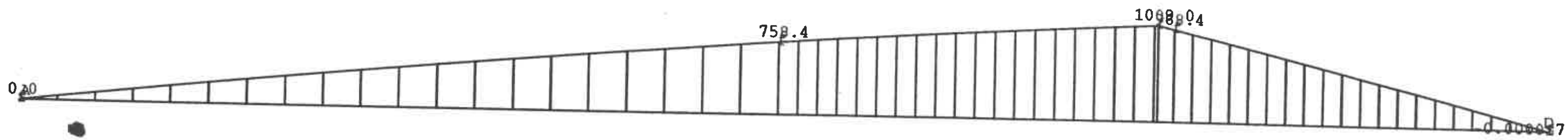
ORIENTATION



HORIZONTAL SCALE = .4229 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0



MAX. DISPLACEMENT FROM LONG ACTING LOAD ~ 5 mm

MOMENT DISTRIBUTION - TERTIARY BEAM B1303

4.1 - 35

SHEET A

T-SHAPED BEAM
TERTIARY BEAM
1. LEVEL AT MIDSPAN

GEOMETRY				
Height, h	=			= 650 mm
Width top., b_t	=			= 1.200 mm
Width bot., b_b	=			= 600 mm
Flange thick., t	=			= 350 mm
Cover layer, c	=			= 57 mm
Eff. height, h_0	=	h -c		= 593 mm
Length, l	=			= 4,25 m
REINFORCEMENT				
No. of bars	=			= 8 pcs. } BOTTOM
Bar diameter	=			= 32 mm }
F_a	=			= 6434 mm^2
fi (T-beam)	=	F_a / (h * b_f) = F_a / (h * (b_b + 2*t))	>fi_min OK	= 0,76 %
fi (rect. beam)	=	F_a / (h * b_b)	>fi_min OK	= 1,65 %
MATERIALS				
R_b	=			= 17,1 MPa
R_bk	=			= 22,2 MPa
R_bzk	=			= 1,7 MPa
R_bz	=			= 1,2 MPa
R_a	=			= 350 MPa
R_ak	=			= 410 MPa
n_short time	=			= 6,48
n_long time	=			= 33,00
E-ak	=			= 210.000 MPa
E_b	=			= 32.400 MPa
fi_min	=	0,45 *R_bzk /R_ak		= 0,19 %
LOADS				
M_ult	=			= 1009 kNm
M_k (short time)	=	(50% live load, characteristic load)		= 333 kNm
M_d (long time)	=	(50% live load + 100% dead load, characteristic load)		= 505 kNm
kap_f	=	1+0,5*(M_k/(M_k+M_d))		= 1,20
M_c	=	M_k+kap_f*M_d		= 938 kNm
ULTIMATE LOAD BEARING CAPACITY		acc. to ds 411		
omega_bal	=			= 0,50
omega	=	(F_a*R_a)/(b_t*h_0*R_b)	< omega_bal OK	= 0,1851
my	=	(1-½*omega)*omega		= 0,1679
beta	=	1,25 * omega		= 0,2313
h_c	=	beta * h_0	<1,33 * t OK	= 137,2 mm
M_u,d (+)	=	my * b * h_0^2 * R_b	>M_ult	= 1.212 kNm
"Safety"	=	M_u,d(+) / M_ult		Load bearing capacity OK = 1,20
ULTIMATE LOAD BEARING CAPACITY		acc. to polish standard		
X	=	(R_a*F_a)/(b_t*R_b)		= 109,74 mm
psi	=	X/h_0		= 0,19 <psi_gr, OK
psi_gr	=			= 0,50
M_ud	=	R_a*F_a*(h_0 - 0.5*X)	>M_ult	= 1212 KNm
"Safety"	=	M_u,d(+) / M_ult		Load bearing capacity OK = 1,20

METHODE B:
ELASTIC ANALYSIS

SHORT TIME		DS 411		
fi	=	F_a / b_t /h_0	=	0,0090
n * fi	=		=	0,059
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)	=	0,289
y_0	=	beta * h_0	=	171 mm
		<1,25 * t, OK		
fi_b	=	beta/6*(3-beta)	=	0,130
gamma	=	(1 - beta) / beta	=	2,463
sigma_c, max	=	M_k / (fi_b*b_t*h_0^2)	=	6,0 MPa
sigma_a, max	=	n * gamma * sigma_c,max	=	97 MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)	=	267 mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5	=	0,08 mm
				(CRACK WIDTH)
u_0	=	n * sigma_a,max * l^2 / (10 * y_0 * E_ak)	=	2,0 mm
				(DEFLECTION)
l / u_0	=		=	2.158

LONG TIME		DS 411		
fi	=	F_a / b_t /h_0	=	0,0090
n * fi	=		=	0,298
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)	=	0,530
y_0	=	beta * h_0	=	314
		<1,25 * t, OK		
fi_b	=	beta/6*(3-beta)	=	0,218
rho	=	beta*fi_b	=	0,116
I_zt	=	rho*b_t*h_0^3	=	2,9E+10 mm^4
gamma	=	(1 - beta) / beta	=	0,888
sigma_c, max	=	M_d / (fi_b*b_t*h_0^2)	=	5,5 MPa
sigma_a, max	=	n * gamma * sigma_c,max	=	161 MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)	=	267 mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5	=	0,13 mm
u_0	=	n * sigma_c,max * l^2 / (10 * y_0 * E_ak)	=	5,0 mm
l / u_0	=		=	857

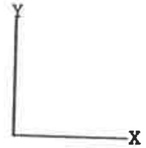
Crackwidth acc. to Polish standard

gam_a	=		=	0,00
gam_b	=	(b_t-b_b)*t/(b_b*h_0)	=	0,590
L	=	M_c/(R_bk*b_b*h_0^2)	=	0,20
G	=	gam_b*(1-t/(2*h_0))+gam_a*(1-a/h_0)	=	0,416
my_a	=	F_a/(b_b*h_0)	=	0,018
psi_f	=	1/(1,8+(1+5*(L+G))/(10*n*my_a))	=	0,189
		< t/h_0 , OK !		
Z_f	=	FORMULA (Z5-9)	=	447 mm
sigma_a	=	M_c/(Z_f*F__a)	=	326 MPa

n	=	E_ak/E_b	=	6,48
delta_1	=	(b_t-b_b)*t/(b_b*h)	=	0,54
M_fp	=	[0,292+1,5*n/(b_b*h)*(F_a+0,1*F_ac)+0,15*delta_1]*b_b*h^2*R_bzk	=	234 kNm
psi_a	=	1,3-0,8*M_fp/M_c	=	1,000
K_1	=	M_fp/(Z_f*n*F_a*R_bzk) - 2	=	5,25
l_f	=	K_1*n*F_a/(sum u_a)*n_f	=	191 mm
a_sr	=	psi_a*(sigma_a/E_ak)*l_f	=	0,296
k_f	=		=	1,000
a_f	=	k_f*a_sr	=	0,296 mm
		<0,3 mm, OK		

SHEAR REINFORCEMENT

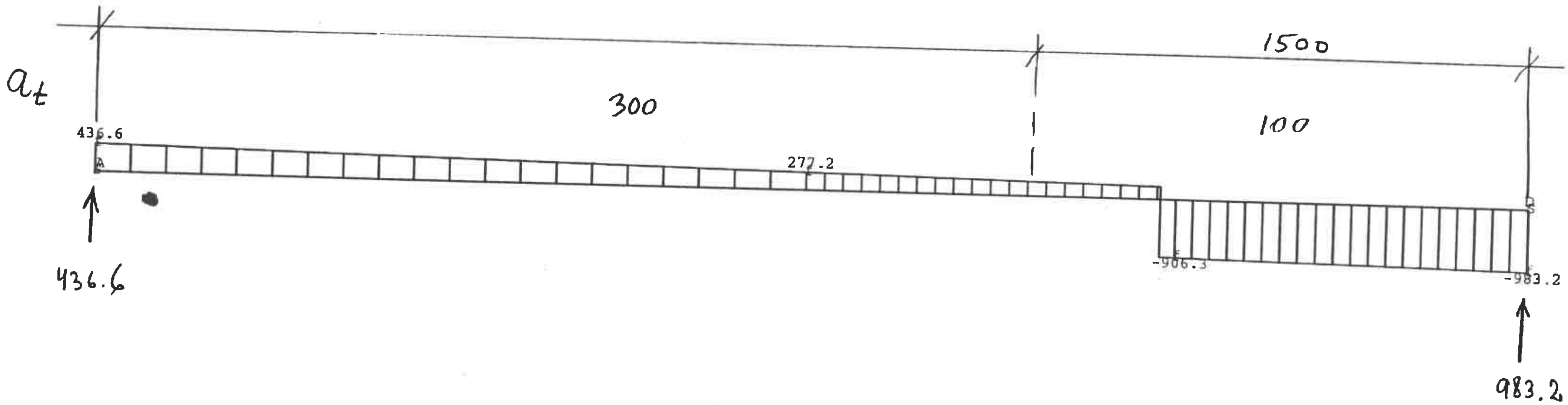
ORIENTATION



HORIZONTAL SCALE = .4229 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0



SHEAR FORCE DISTRIBUTION - TERTIARY BEAM B1303

4.1-37

4.1-38

SHEAR CALCULATION acc. to polish standard RIGHT

STIRRUPS				
Bar diameter, d_s				
No. of sections	=		=	16 mm
F_s	=		=	4
gam_f0	=		=	804 mm^2
sigma_p	=	(VALUE TAKEN FROM TABLE 12 IN PN-84/B-3264)	=	1,2
sigma_ps	=	sigma_p/sqrt(0.1*d_s)	=	387 N/mm^2
sigma_max	=	0,8*R_as**R_b*b_b*h_0/(2.4*gam_f0*Q_1)	=	306 N/mm^2
			=	481 N/mm^2
		sigma_ps < sigma_max, OK		

Q_1	=		=	983 kN
Q_min	=	0.75*R_bz*b_b*h_0	=	307 kN
Q_max	=	0,25*R_b*b_b*h_0	=	1521 kN
		> Q_1, OK		
q	=		=	75 kN/m
SUM_Ni	=		=	0 kN
		(SUM_Ni is sum of konc. loads between Q_1 and Q_min)		
c_0	=	(Q_1-Q_MIN-SUM_Ni)/q	=	9,015 m
		c_0 > h_0 , Q_2,Q_3 ... COULD BE GIVEN !!!		
c_01	=	(IF c_0 < h_0 THEN c_01 = c_0)	=	1,07 m
T_1	=	Q_1*c_01/h_0	=	1774 kN
n_s	=	T_1/(gam_f0*sigma_ps*F_s)	=	7
a_t	=	c_01/n_s	=	153 mm
fi_min	=	0,2*R_bzk/0,8*R_ak	=	0,105 %
a_t,min,1	=	F_s/(fi_min*b_b)	=	1271 mm
				or
a_t,min,2	=	0,7*h	=	455 mm
a_t,min	=	MIN(a_t,min,1 ; a_t,min,2)	=	455 mm
		> a_t, OK		

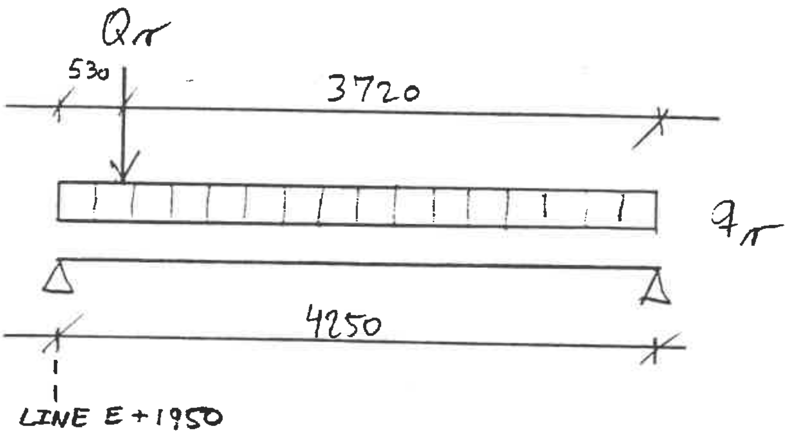
4.1-39

STIRRUPS

Bar diameter, d_s			=	16 mm
No. of sections =			=	4
F_s	=		=	804 mm^2
gam_f0	=		=	1,2
sigma_p	=	(VALUE TAKEN FROM TABLE 12 IN PN-84/B-3264)	=	387 N/mm^2
sigma_ps	=	sigma_p/sqrt(0.1*d_s)	=	306 N/mm^2
sigma_max	=	0,8*R_as**R_b*b_b*h_0/(2.4*gam_f0*Q_1)	=	1083 N/mm^2
		sigma_ps < sigma_max, OK		

Q_1	=		=	437 kN
Q_min	=	0.75*R_bz*b_b*h_0	=	307 kN
Q_max	=	0,25*R_b*b_b*h_0	=	1521 kN
		> Q_1, OK		
q	=		=	75 kN/m
SUM_Ni	=		=	0 kN
	(SUM_Ni is sum of konc. loads between Q_1 and Q_min)			
c_0	=	(Q_1-Q_MIN-SUM_Ni)/q	=	1,735 m
		c_0 > h_0 , Q_2,Q_3 ... COULD BE GIVEN !!!		
c_01	=	(IF c_0 < h_0 THEN c_01 = c_0)	=	1,735 m
T_1	=	Q_1*c_01/h_0	=	1279 kN
n_s	=	T_1/(gam_f0*sigma_ps*F_s)	=	5
a_t	=	c_01/n_s	=	347 mm
fi_min	=	0,2*R_bzk/0,8*R_ak	=	0,105 %
a_t,min,1	=	F_s/(fi_min*b_b)	=	1271 mm
			or	
a_t,min,2	=	0,7*h	=	455 mm
a_t,min	=	MIN(a_t,min,1 ; a_t,min,2)	=	455 mm
		> a_t, OK		

4.1.4.4 B 1304

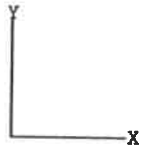


q_r :	TOTAL DEAD LOAD	= 30 kN/m
	TOTAL LIVE LOAD	= 45 kN/m
		75 kN/m
Q_r :	TOTAL LIVE LOAD	= 910 kN

REINFORCEMENT: REFER B 1303.

BENDING REINFORCEMENT 8 Φ32 BOTTOM

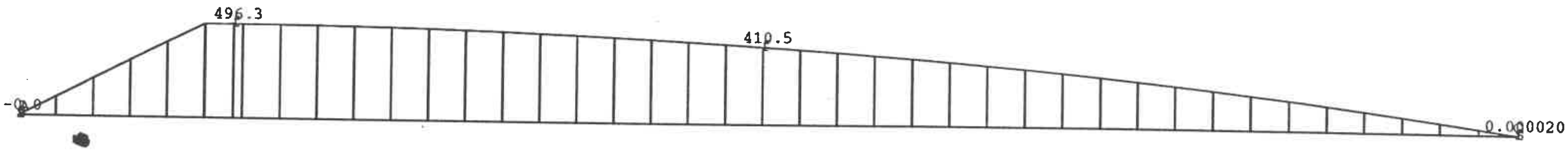
ORIENTATION



HORIZONTAL SCALE = .4229 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0



MOMENT DISTRIBUTION - TERTIARY BEAM B1304

4.1-41

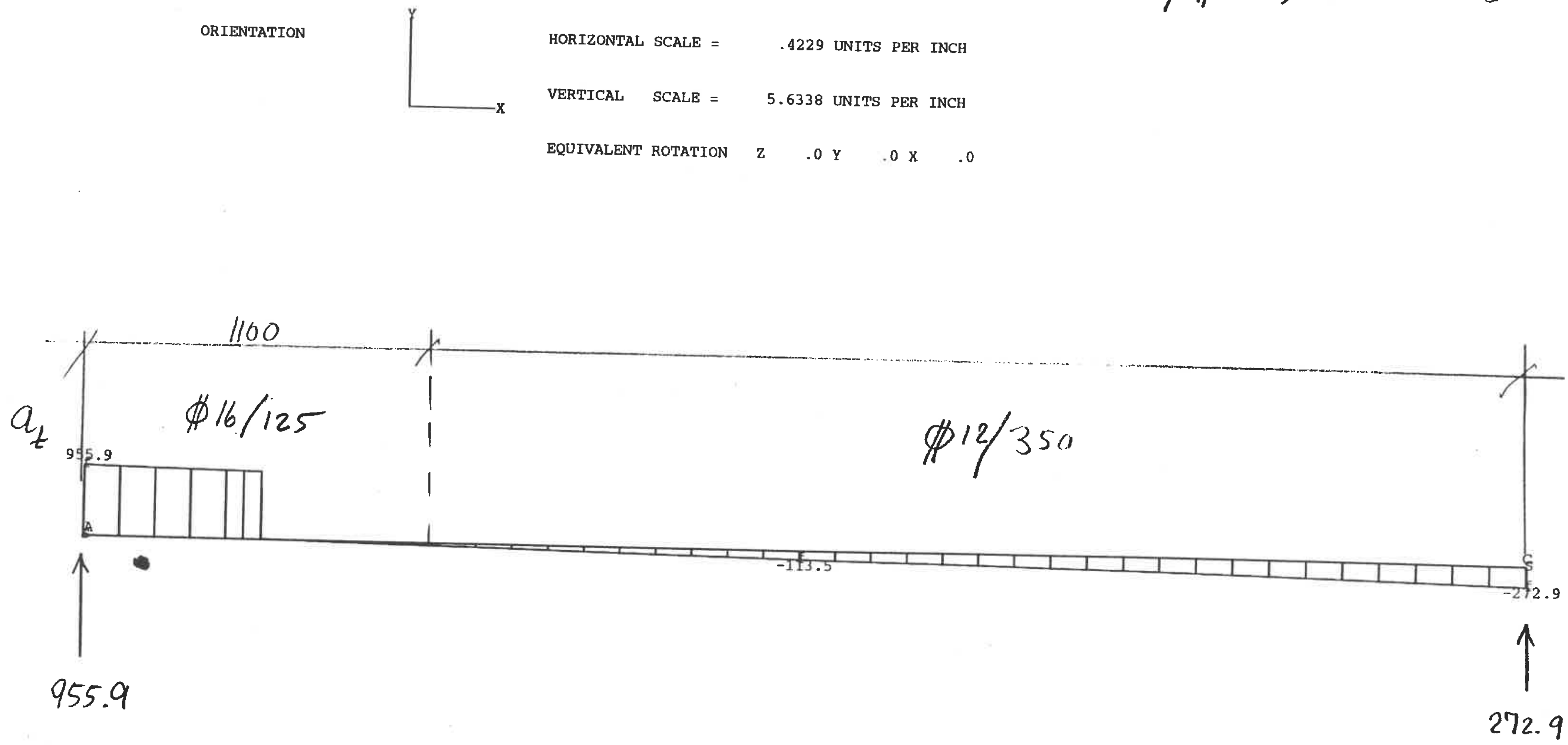
SHEAR REINFORCEMENT   Φ12/Φ16 , 4 SECTIONS

ORIENTATION

HORIZONTAL SCALE = .4229 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0

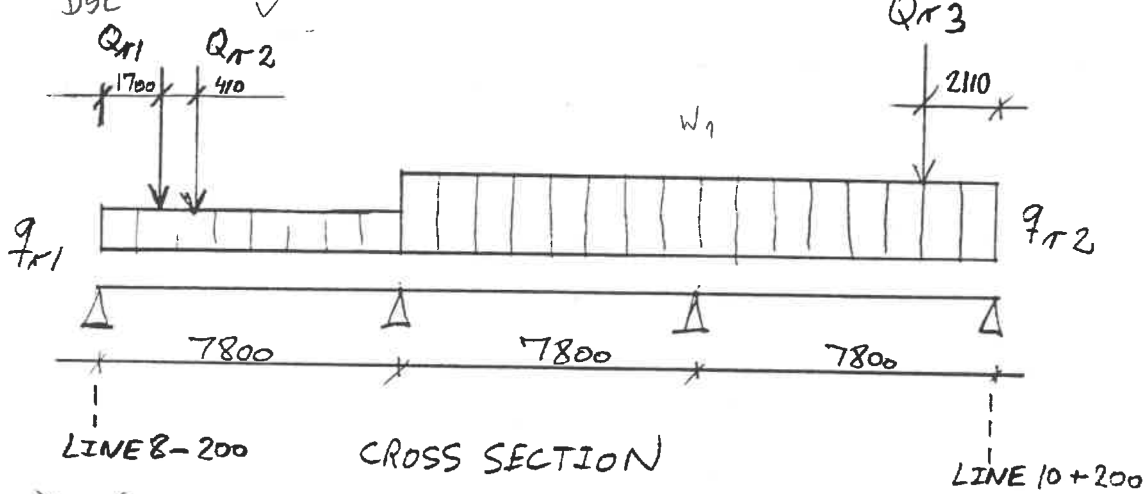


SHEAR FORCE DISTRIBUTION - TERTIARY BEAM B1304

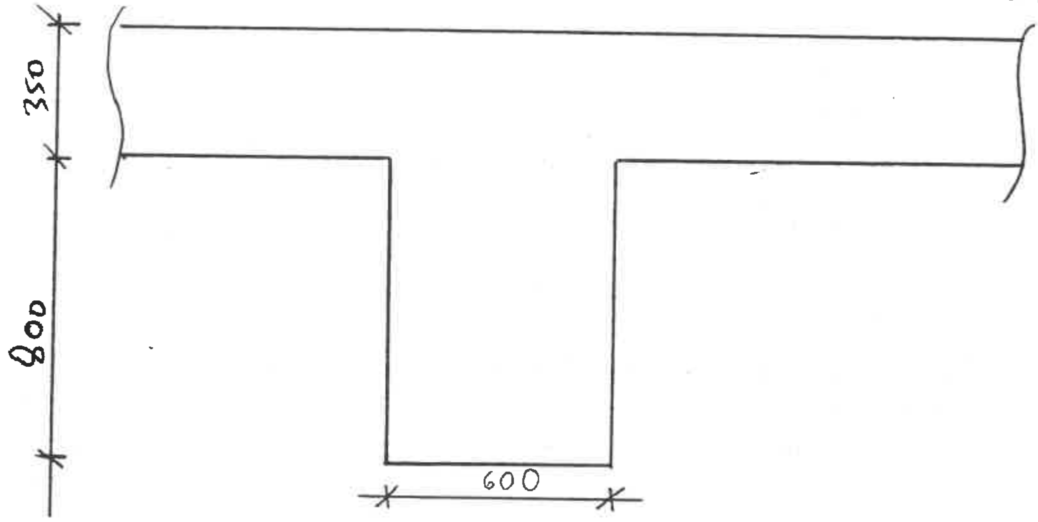
4.1-42

4.1.5 SECONDARY BEAMS

4.1.5.1 B1261, B1262, B1263



CROSS SECTION



DEAD LOAD FROM BEAM:

$0.8 \cdot 0.6 \cdot 25 \cdot 1.1 = 13.2\ kN/m$

LINE LOAD FROM ADJACENT SLABS AND EQUIPMENT:

q_{r1} : DEAD LOAD $\frac{10.63}{120.63} \cdot 214 \cdot 2 = 37.7\ kN/m$

LIVE LOAD $\frac{13}{120.63} \cdot 214 \cdot 2 = 46.1\ kN/m$

$83.8\ kN/m$

q_{r2} : DEAD LOAD $\frac{10.63}{120.63} \cdot 214 \cdot 2 = 37.7$ kN/m

LIVE LOAD $\frac{13}{120.63} \cdot 214 \cdot 2 + 76 = 122.1$ kN/m

159.8 kN/m

Q_{r1} : LIVE LOAD = 165 kN

Q_{r2} : LIVE LOAD = 983.2 kN

Q_{r3} : LIVE LOAD = 955.9 kN

q_{r1} : TOTAL DEAD LOAD = 51 kN/m

TOTAL LIVE LOAD = 46 kN/m

97 kN/m

q_{r2} : TOTAL DEAD LOAD = 51 kN/m

TOTAL LIVE LOAD = 122 kN/m

173 kN/m

Q_{r1} : TOTAL LIVE LOAD = 165 kN

Q_{r2} : TOTAL LIVE LOAD = 983 kN

Q_{r3} : TOTAL LIVE LOAD = 956 kN

$$\frac{7,8}{7,8 - 2,125} = 1,374$$

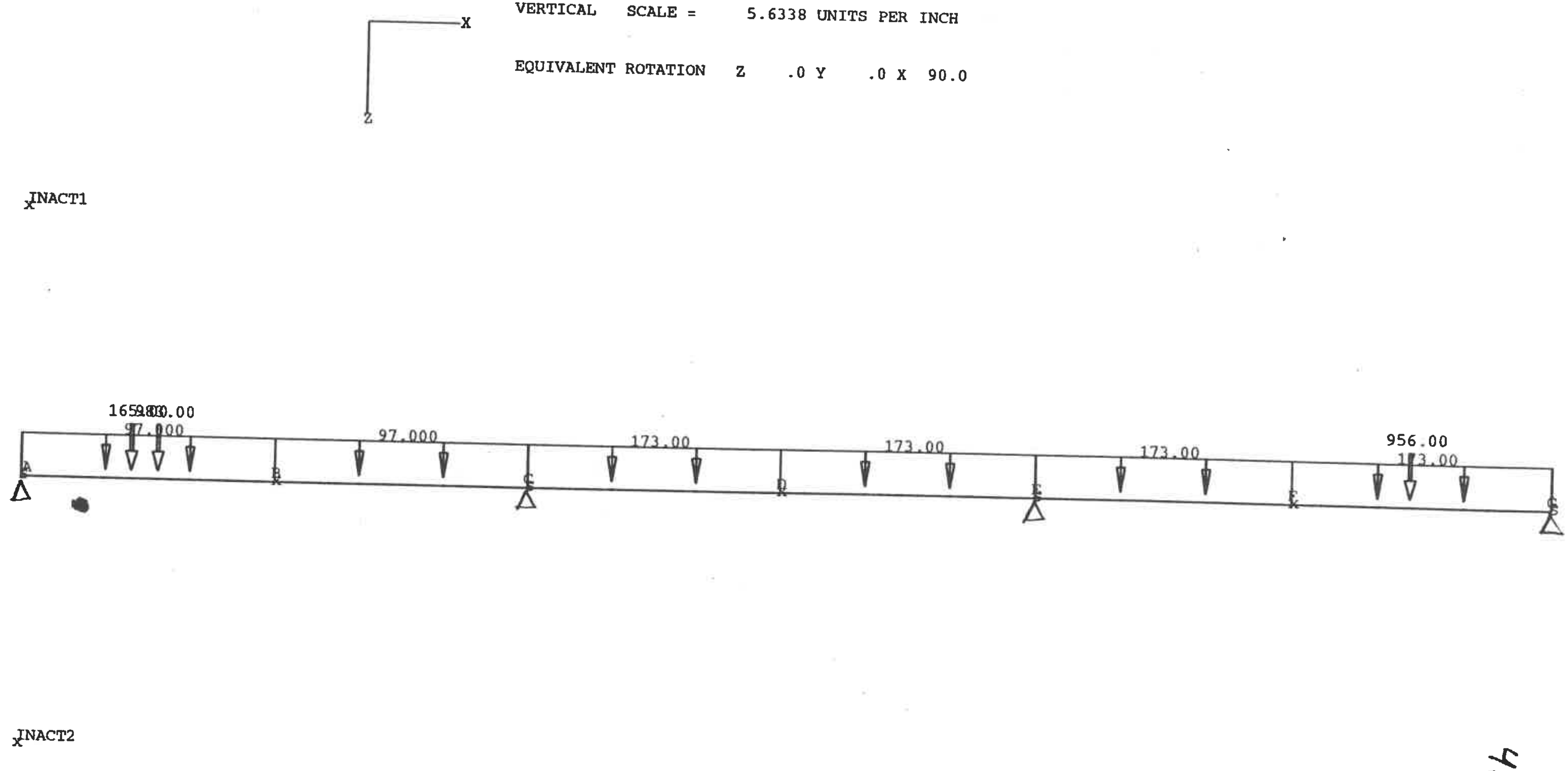
LOAD COMBINATIONS

ORIENTATION

HORIZONTAL SCALE = 2.3284 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

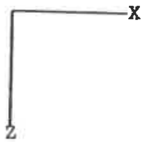
EQUIVALENT ROTATION Z .0 Y .0 X 90.0



LOAD 1 - SEC. BEAM LEVEL 1, LINE E+1950

4.1-45

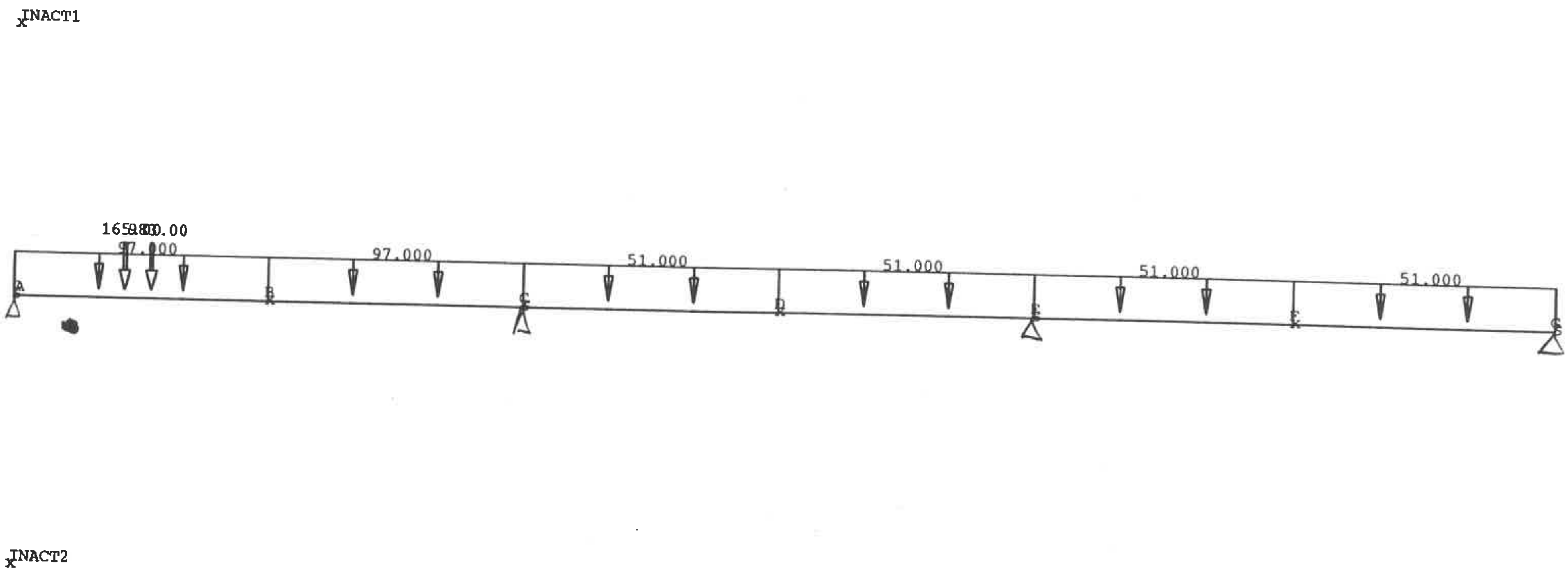
ORIENTATION



HORIZONTAL SCALE = 2.3284 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

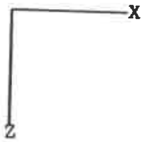
EQUIVALENT ROTATION Z .0 Y .0 X 90.0



LOAD 2 - SEC. BEAM LEVEL 1, LINE E+1950

4.1-46

ORIENTATION

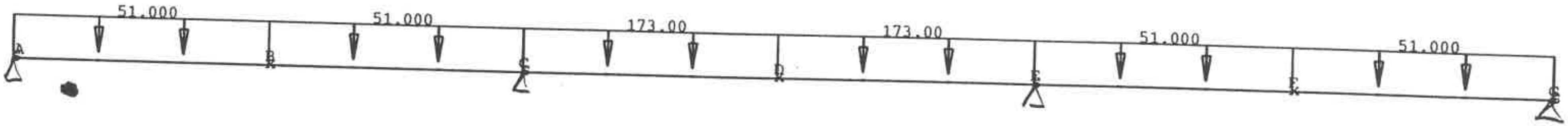


HORIZONTAL SCALE = 2.3284 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X 90.0

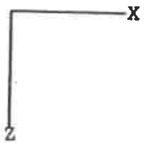
INACT1



INACT2

LOAD 3 - SEC. BEAM LEVEL 1, LINE E+1950

ORIENTATION

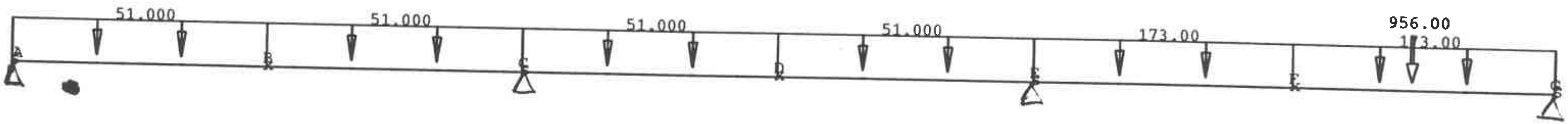


HORIZONTAL SCALE = 2.3284 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X 90.0

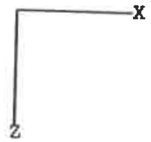
x INACT1



x INACT2

LOAD 4 - SEC. BEAM LEVEL 1, LINE E+1950

ORIENTATION

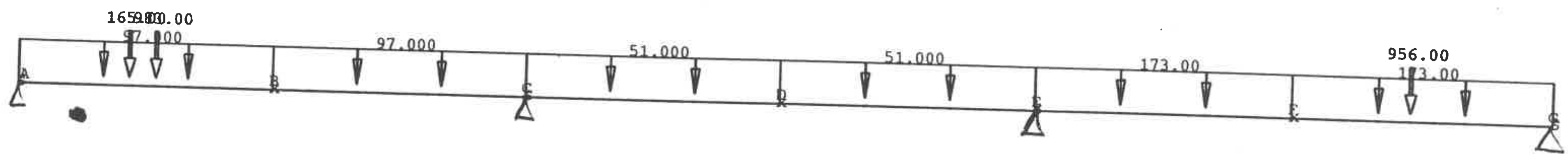


HORIZONTAL SCALE = 2.3284 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X 90.0

x INACT1

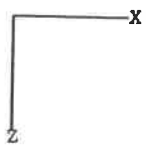


x INACT2

LOAD 5 - SEC. BEAM LEVEL 1, LINE E+1950

4.1-49

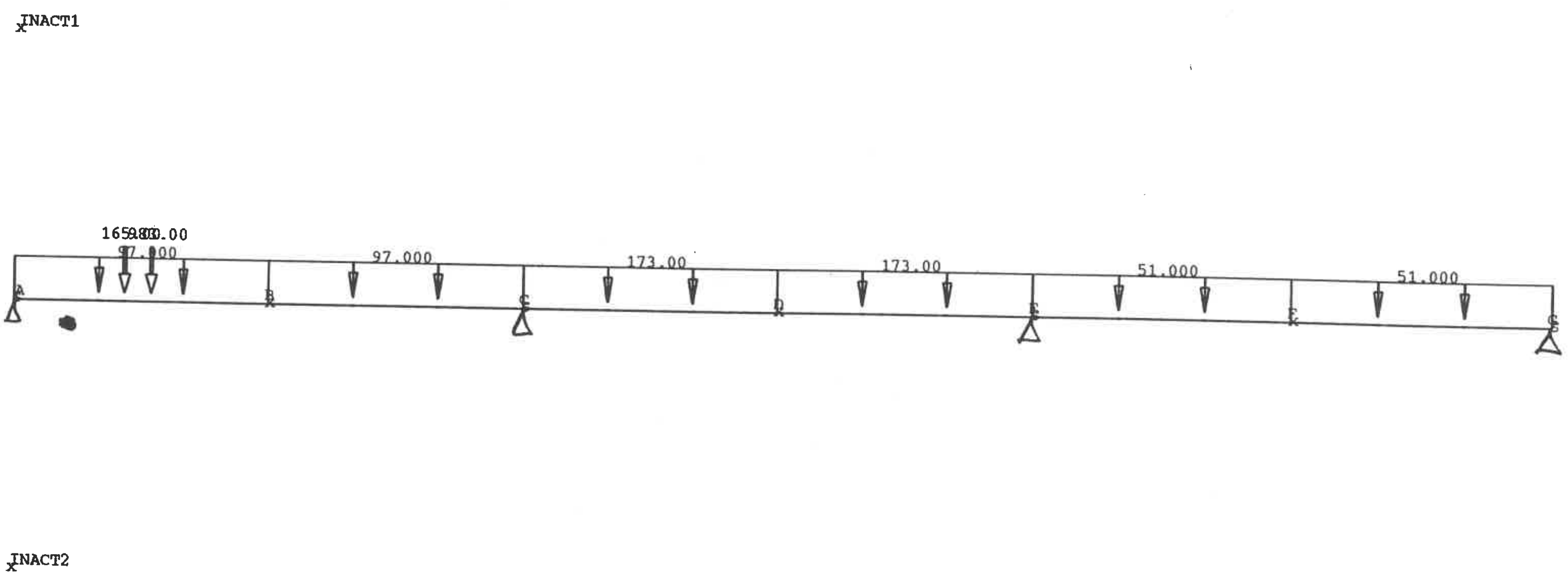
ORIENTATION



HORIZONTAL SCALE = 2.3284 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

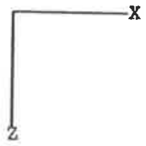
EQUIVALENT ROTATION Z .0 Y .0 X 90.0



LOAD 6 - SEC. BEAM LEVEL 1, LINE E+1950

4.1-50

ORIENTATION

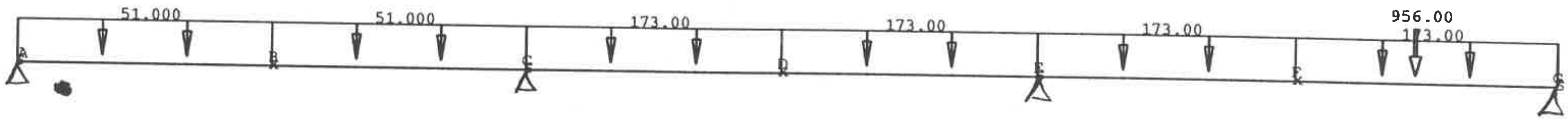


HORIZONTAL SCALE = 2.3284 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X 90.0

INACT1

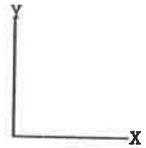


INACT2

LOAD 7 - SEC. BEAM LEVEL 1, LINE E+1950

MOMENT ENVELOPE

ORIENTATION

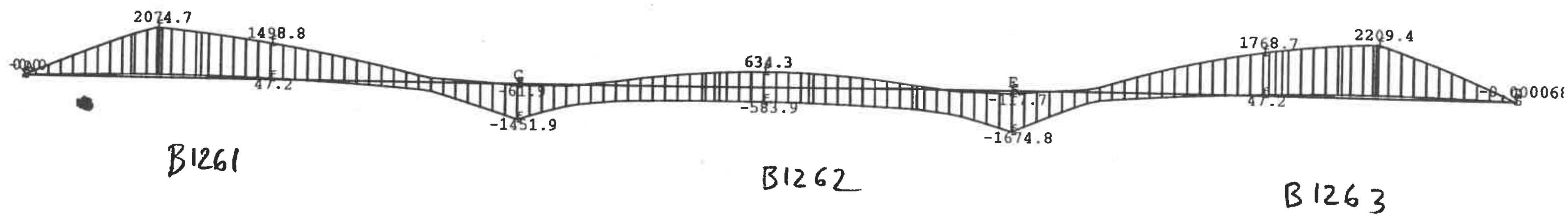


HORIZONTAL SCALE = 2.3284 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0

NOS. OF LOAD COMBINATIONS = 7



MOMENT ENV. - SEC. BEAM LEVEL 1, LINE E+1950

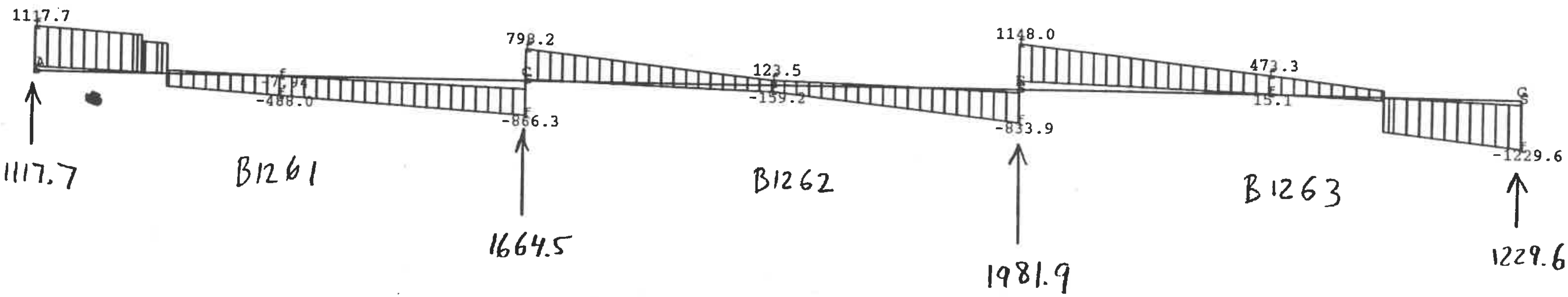
SHEAR FORCE ENVELOPE

ORIENTATION

HORIZONTAL SCALE = 2.3284 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

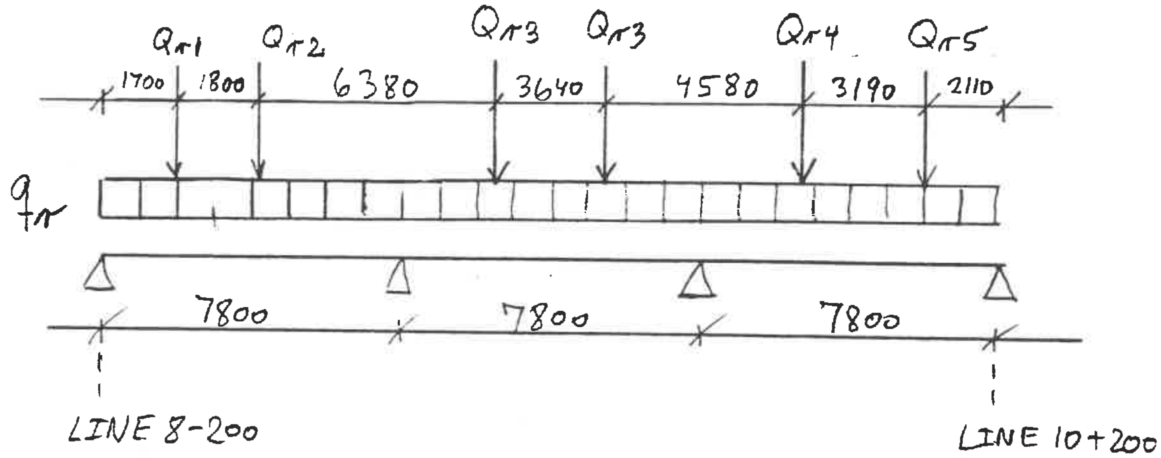
EQUIVALENT ROTATION Z .0 Y .0 X .0



SHEAR FORCE ENV. - SEC. BEAM LEVEL 1, LINE E+1950

4.1-53

4.1.5.2 B1271, B1272, B1273

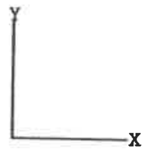


CROSS SECTION IS THE SAME AS FOR B1261, B1262, B1263.

q_r : TOTAL DEAD LOAD		= 51 kN/m
TOTAL LIVE LOAD	$\frac{13}{120.63} \cdot 214 \cdot 2$	= 46 kN/m
		97 kN/m
Q_{r1} : TOTAL LIVE LOAD		= 168 kN
Q_{r2} : TOTAL LIVE LOAD		= 426 kN
Q_{r3} : TOTAL LIVE LOAD		= 450 kN
Q_{r4} : TOTAL LIVE LOAD		= 376 kN
Q_{r5} : TOTAL LIVE LOAD		= 273 kN

MOMENT ENVELOPE

ORIENTATION

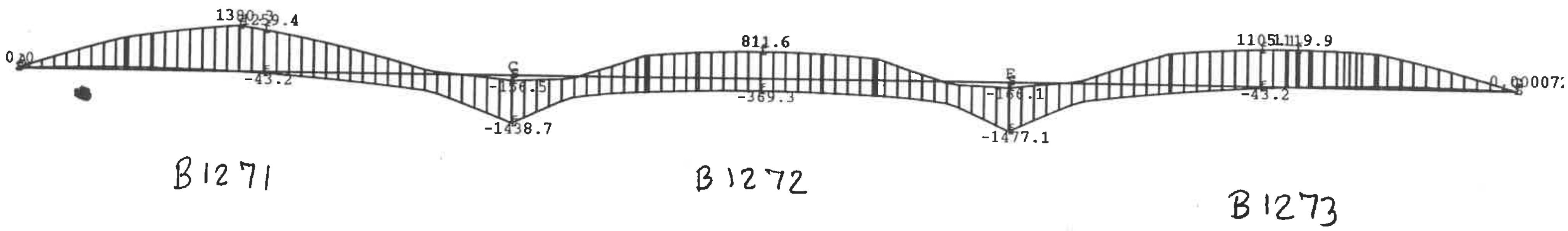


HORIZONTAL SCALE = 2.3284 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0

NO. OF LOAD COMB. = 7

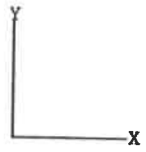


MOMENT ENV. - SEC. BEAM LEVEL 1, LINE F-400

4.1-55

SHEAR FORCE ENVELOPE

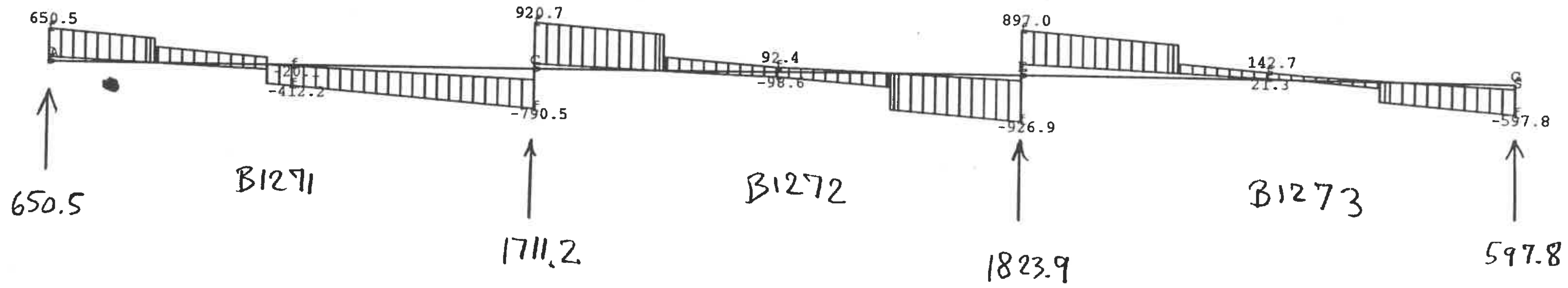
ORIENTATION



HORIZONTAL SCALE = 2.3284 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

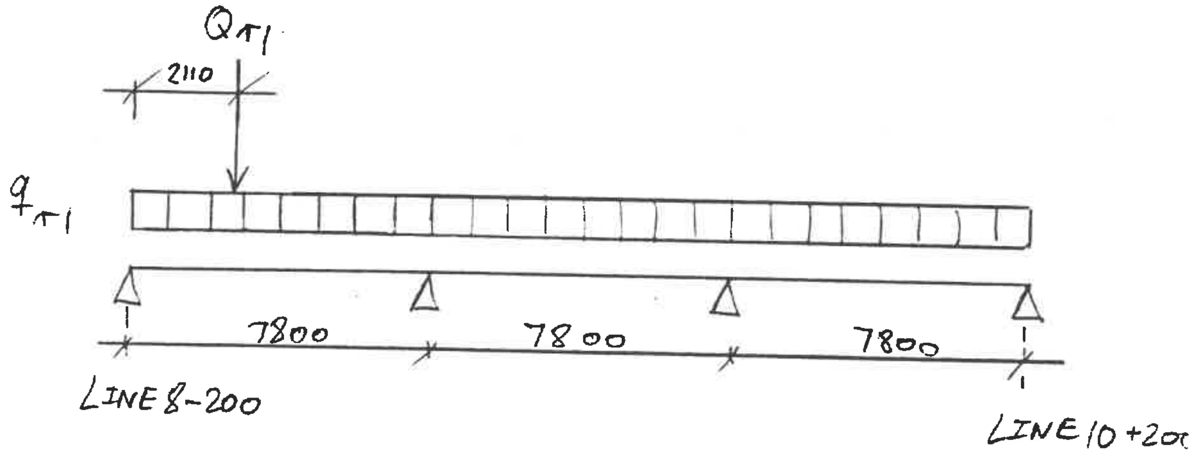
EQUIVALENT ROTATION Z .0 Y .0 X .0



SHEAR FORCE ENV. - SEC. BEAM LEVEL 1, LINE F-400

4.1-56

4.1.5.3 B1251, B1252, B1253



CROSS SECTION IS THE SAME AS FOR B1261, B1262, B1263.

q_{T1} : TOTAL DEAD LOAD $23 + \frac{10.63}{120.63} \cdot 214 + \frac{5.5}{23} \cdot 47.9 + 13.2 = 67$ kN/m

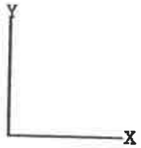
TOTAL LIVE LOAD $\frac{13}{120.63} \cdot 214 + \frac{8.6}{23} \cdot 47.9 = 41$ kN/m

108 kN/m

Q_{T1} : TOTAL LIVE LOAD 437 kN

MOMENT ENVELOPE

ORIENTATION

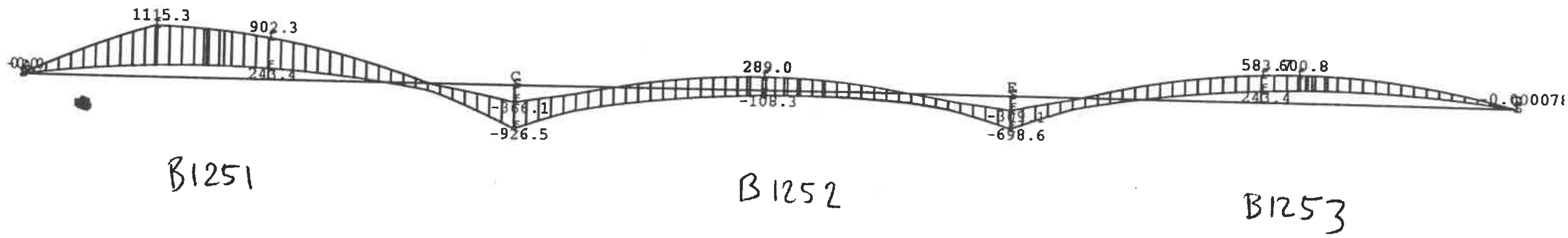


HORIZONTAL SCALE = 2.3284 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0

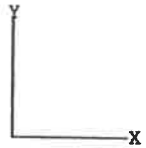
NOS. OF LOAD COMB. = 7



MOMENT ENV. - SEC. BEAM LEVEL 1, LINE D+4300

SHEAR FORCE ENVELOPE

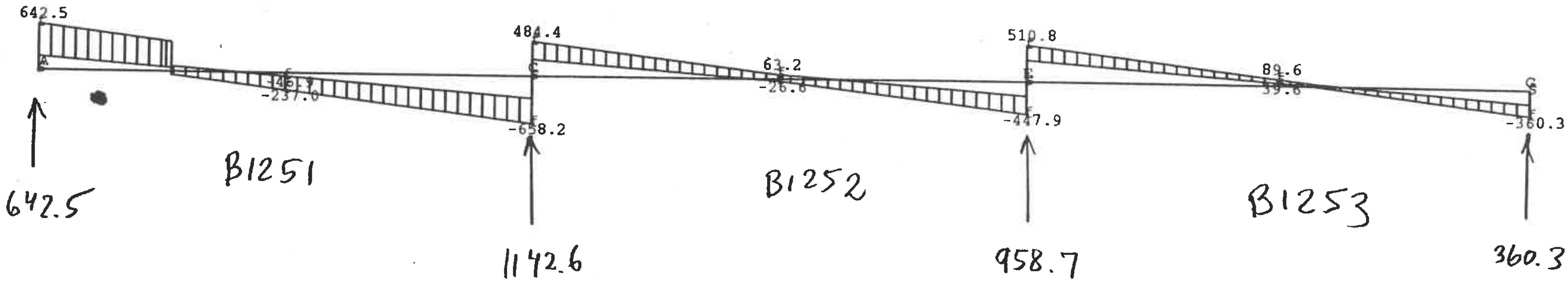
ORIENTATION



HORIZONTAL SCALE = 2.3284 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0



SHEAR FORCE ENV. - SEC. BEAM LEVEL 1, LINE D+4300

4.1-59

4.1.5.4 ENVELOPE OF B1251, B1252, B1253, B1261, B1262, B1263, B1271, B1272, B1273

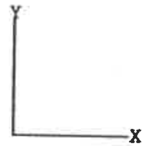
BENDING REINFORCEMENT

TABLE BELOW SHOWS ALLOWABLE MOMENTS IN CROSS SECTION, WITH RESPECT TO ULTIMATE LOAD CAPACITY AND CRACK WIDTH:

NO. Ø25 (TOP/BOTTOM)	MAX. MOMENT [kNm]
16	> 2209
14	1900
12	1600
10	1300
8	1000
6	700
4	400
2	300

MOMENT ENVELOPE

ORIENTATION

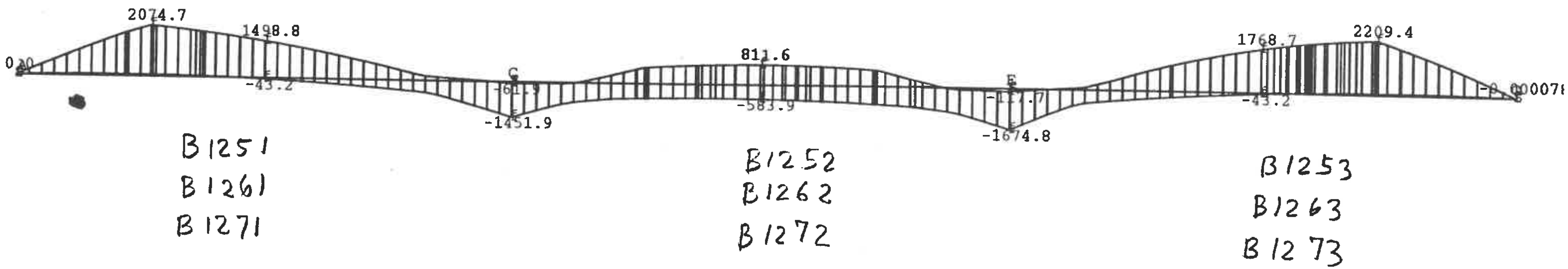


HORIZONTAL SCALE = 2.3284 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0

NOS. OF LOAD COMB. = 21



MOMENT ENV. - SEC. BEAM LEVEL 1, LINE D+4300,E+1950,F-400

4.1 - 63

SHEET A

T-SHAPED BEAM
SECONDARY BEAM
1. LEVEL AT MIDSPAN

GEOMETRY

Height, h	=		=	1.150 mm
Width top., b_t	=		=	1.200 mm
Width bot., b_b	=		=	600 mm
Flange thick., t	=		=	350 mm
Cover layer, c	=		=	79 mm
Eff. height, h_0	=	h -c	=	1071 mm
Length, l	=		=	7,8 m

REINFORCEMENT

No. of bars	=		=	16 pcs. } BOTTOM
Bar diameter	=		=	25 mm
F_a	=		=	7854 mm^2
fi (T-beam)	=	F_a / (h * b_f) = F_a / (h * (b_b + 2*t))	=	0,53 %
		>fi_min OK		
fi (rect. beam)	=	F_a / (h * b_b)	=	1,14 %
		>fi_min OK		

MATERIALS

R_b	=		=	17,1 MPa
R_bk	=		=	22,2 MPa
R_bzk	=		=	1,7 MPa
R_bz	=		=	1,2 MPa
R_a	=		=	350 MPa
R_ak	=		=	410 MPa
n_short time	=		=	6,48
n_long time	=		=	33,00
E-ak	=		=	210.000 MPa
E_b	=		=	32.400 MPa
fi_min	=	0,45 *R_bzk /R_ak	=	0,19 %

LOADS

M_ult	=		=	2209 kNm
M_k (short time)	=	(50% live load, characteristic load)	=	751 kNm
M_d (long time)	=	(50% live load + 100% dead load, characteristic load)	=	1082 kNm
kap_f	=	1+0,5*(M_k/(M_k+M_d))	=	1,20
M_c	=	M_k+kap_f*M_d	=	2.055 kNm

ULTIMATE LOAD BEARING CAPACITY acc. to ds 411

omega_bal	=		=	0,50
omega	=	(F_a*R_a)/(b_t*h_0*R_b)	=	0,1251
		< omega_bal OK		
my	=	(1-½*omega)*omega	=	0,1173
beta	=	1,25 * omega	=	0,1564
h_c	=	beta * h_0	=	167,5 mm
		<1,33 * t OK		
M_u,d (+)	=	my * b * h_0^2 * R_b	=	2.760 kNm
		>M_ult		Load bearing capacity OK
"Safety"	=	M_u,d(+) / M_ult	=	1,25

ULTIMATE LOAD BEARING CAPACITY acc. to polish standard

X	=	(R_a*F_a)/(b_t*R_b)	=	133,96 mm
psi	=	X/h_0	=	0,13 <psi_gr, OK
psi_gr	=		=	0,50
M_ud	=	R_a*F_a*(h_0 - 0.5*X)	=	2760 KNm
		>M_ult		Load bearing capacity OK
"Safety"	=	M_u,d(+) / M_ult	=	1,25

4.1-64

METHODE B:
ELASTIC ANALYSIS

SHORT TIME		DS 411			
fi	=	F_a / b_t /h_0		=	0,0061
n * fi	=			=	0,040
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)		=	0,245
y_0	=	beta * h_0	<1,25 * t, OK	=	262 mm
fi_b	=	beta/6*(3-beta)		=	0,112
gamma	=	(1 - beta) / beta		=	3,088
sigma_c, max	=	M_k / (fi_b*b_t*h_0^2)		=	4,9 MPa
sigma_a, max	=	n * gamma * sigma_c,max		=	97 MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)		=	237 mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5		=	0,07 mm (CRACK WIDTH)
u_0	=	n * sigma_a,max * l^2 / (10 * y_0 * E_ak)		=	3,5 mm (DEFLECTION)
l / u_0	=			=	2.241

LONG TIME		DS 411			
fi	=	F_a / b_t /h_0		=	0,0061
n * fi	=			=	0,202
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)		=	0,465
y_0	=	beta * h_0	<1,25 * t, OK	=	498
fi_b	=	beta/6*(3-beta)		=	0,196
rho	=	beta*fi_b		=	0,091
I_zt	=	rho*b_t*h_0^3		=	1,3E+11 mm^4
gamma	=	(1 - beta) / beta		=	1,152
sigma_c, max	=	M_d / (fi_b*b_t*h_0^2)		=	4,0 MPa
sigma_a, max	=	n * gamma * sigma_c,max		=	152 MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)		=	237 mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5		=	0,12 mm
u_0	=	n * sigma_c,max * l^2 / (10 * y_0 * E_ak)		=	7,7 mm
l / u_0	=			=	1.014

Crackwidth acc. to Polish standard

gam_a	=			=	0,00
gam_b	=	(b_t-b_b)*t/(b_b*h_0)		=	0,327
L	=	M_c/(R_bk*b_b*h_0^2)		=	0,13
G	=	gam_b*(1-t/(2*h_0))+gam_a*(1-a/h_0)		=	0,273
my_a	=	F_a/(b_b*h_0)		=	0,012
psi_f	=	1/(1,8+(1+5*(L+G))/(10*n*my_a))	< t'/h_0 , OK !	=	0,177
Z_f	=	FORMULA (Z5-9)		=	924 mm
sigma_a	=	M_c/(Z_f*F__a)		=	283 MPa

n	=	E_ak/E_b	=	6,48
delta_1	=	(b_t-b_b)*t/(b_b*h)	=	0,30
M_fp	=	[0,292+1,5*n/(b_b*h)*(F_a+0,1*F_ac)+0,15*delta_1]*b_b*h^2*R_bzk	=	615 kNm
psi_a	=	1,3-0,8*M_fp/M_c	=	1,000
K_1	=	M_fp/(Z_f*n*F_a*R_bzk) - 2	=	5,56
l_f	=	K_1*n*F_a/(sum u_a)*n_f	=	158 mm
a_sr	=	psi_a*(sigma_a/E_ak)*l_f	=	0,213
k_f	=		=	1,187
a_f	=	k_f*a_sr	=	0,252 mm

<0,3 mm, OK

4,1-65

T-SHAPED BEAM
SECONDARY BEAM
1. LEVEL AT SUPPORT

SHEET A

GEOMETRY

Height, h	=			= 1.150 mm
Width top., b_t	=			= 600 mm
Width bot., b_b	=			= 600 mm
Flange thick., t	=			= 350 mm
Cover layer, c	=			= 79 mm
Eff. height, h_0	=	h -c		= 1071 mm
Length, l	=			= 7,8 m

REINFORCEMENT

No. of bars	=			= 16 pcs. } TOP
Bar diameter	=			= 25 mm } TOP
F_a	=			= 7854 mm^2
fi (T-beam)	=	F_a / (h * b_f) = F_a / (h * (b_b + 2*t))	>fi_min OK	= 0,53 %
fi (rect. beam)	=	F_a / (h * b_b)	>fi_min OK	= 1,14 %

MATERIALS

R_b	=			= 17,1 MPa
R_bk	=			= 22,2 MPa
R_bzk	=			= 1,7 MPa
R_bz	=			= 1,2 MPa
R_a	=			= 350 MPa
R_ak	=			= 410 MPa
n_short time	=			= 6,48
n_long time	=			= 33,00
E-ak	=			= 210.000 MPa
E_b	=			= 32.400 MPa
fi_min	=	0,45 *R_bzk /R_ak		= 0,19 %

LOADS

M_ult	=			= 1675 kNm
M_k (short time)	=	(50% live load, characteristic load)		= 570 kNm
M_d (long time)	=	(50% live load + 100% dead load, characteristic load)		= 821 kNm
kap_f	=	1+0,5*(M_k/(M_k+M_d))		= 1,20
M_c	=	M_k+kap_f*M_d		= 1.559 kNm

ULTIMATE LOAD BEARING CAPACITY acc. to ds 411

omega_bal	=			= 0,50
omega	=	(F_a*R_a)/(b_t*h_0*R_b)	< omega_bal OK	= 0,2502
my	=	(1-½*omega)*omega		= 0,2189
beta	=	1,25 * omega		= 0,3127
h_c	=	beta * h_0	<1,33 * t OK	= 334,9 mm
M_u,d (+)	=	my * b * h_0^2 * R_b	>M_ult	= 2.576 kNm
"Safety"	=	M_u,d(+) / M_ult		Load bearing capacity OK = 1,54

ULTIMATE LOAD BEARING CAPACITY acc. to polish standard

X	=	(R_a*F_a)/(b_t*R_b)		= 267,92 mm
psi	=	X/h_0		= 0,25 <psi_gr, OK
psi_gr	=			= 0,50
M_ud	=	R_a*F_a*(h_0 - 0.5*X)	>M_ult	= 2576 KNm
"Safety"	=	M_u,d(+) / M_ult		Load bearing capacity OK = 1,54

4.1- 66

METHODE B:
ELASTIC ANALYSIS

SHORT TIME		DS 411			
fi	=	F_a / b_t /h_0		=	0,0122
n * fi	=			=	0,079
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)		=	0,327
y_0	=	beta * h_0		=	350 mm
			<1,25 * t, OK		
fi_b	=	beta/6*(3-beta)		=	0,146
gamma	=	(1 - beta) / beta		=	2,062
sigma_c, max	=	M_k / (fi_b*b_t*h_0^2)		=	5,7 MPa
sigma_a, max	=	n * gamma * sigma_c,max		=	76 MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)		=	237 mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5		=	0,06 mm (CRACK WIDTH)
u_0	=	n * sigma_a,max * l^2 / (10 * y_0 * E_ak)		=	3,1 mm (DEFLECTION)
l / u_0	=			=	2.553

LONG TIME		DS 411			
fi	=	F_a / b_t /h_0		=	0,0122
n * fi	=			=	0,403
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)		=	0,581
y_0	=	beta * h_0		=	622
			<1,25 * t, OK		
fi_b	=	beta/6*(3-beta)		=	0,234
rho	=	beta*fi_b		=	0,136
I_zt	=	rho*b_t*h_0^3		=	1,0E+11 mm^4
gamma	=	(1 - beta) / beta		=	0,721
sigma_c, max	=	M_d / (fi_b*b_t*h_0^2)		=	5,1 MPa
sigma_a, max	=	n * gamma * sigma_c,max		=	121 MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)		=	237 mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5		=	0,09 mm
u_0	=	n * sigma_c,max * l^2 / (10 * y_0 * E_ak)		=	7,8 mm
l / u_0	=			=	997

Crackwidth acc. to Polish standard

gam_a	=			=	0,00
gam_b	=	(b_t-b_b)*t/(b_b*h_0)		=	0,000
L	=	M_c/(R_bk*b_b*h_0^2)		=	0,10
G	=	gam_b*(1-t/(2*h_0))+gam_a*(1-a/h_0)		=	0,000
my_a	=	F_a/(b_b*h_0)		=	0,012
psi_f	=	1/(1,8+(1+5*(L+G))/(10*n*my_a))		=	0,270
			< t/h_0 , OK !		
Z_f	=	FORMULA (Z5-9)		=	927 mm
sigma_a	=	M_c/(Z_f*F__a)		=	214 MPa
n	=	E_ak/E_b		=	6,48
delta_1	=	(b_t-b_b)*t/(b_b*h)		=	0,00
M_fp	=	[0,292+1,5*n/(b_b*h)*(F_a+0,1*F_ac)+0,15*delta_1]*b_b*h^2*R_bzk		=	553 kNm
psi_a	=	1,3-0,8*M_fp/M_c		=	1,000
K_1	=	M_fp/(Z_f*n*F_a*R_bzk) - 2		=	4,77
l_f	=	K_1*n*F_a/(sum u_a)*n_f		=	135 mm
a_sr	=	psi_a*(sigma_a/E_ak)*l_f		=	0,138
k_f	=			=	1,559
a_f	=	k_f*a_sr		=	0,215 mm
			<0,3 mm, OK		

CALCULATION OF DEFLECTION

B 1263

TRANSFORMED MOMENT OF INERTIA (REF. SPREAD-SHEET CALC.

$I_{zt} = 1.00 \cdot 10^{11}$ mm^4 (AT SUPPORT)

$I_{zt} = 1.3 \cdot 10^{11}$ mm^4 (AT MIDSPAN)

VALUE USED IN GTSTRUDL MODEL:

$I_{zt} = 1.15 \cdot 10^{11}$ mm^4

LONG ACTING LOAD: (DEAD LOAD + 50% LIVE LOAD)

$$\sim \frac{1}{1.2} \frac{51 + 0.5 \cdot 122 + 0.5 \cdot \frac{956}{7.8}}{51 + 122 + 956/7.8} \cdot 100\% = 49\%$$

$E = 6400\ N/mm^2$ OF TOTAL DESIGN LOAD

SHORT ACTING LOAD: (50% LIVE LOAD)

$$\frac{1}{1.2} \frac{0.5 \cdot 122 + 0.5 \cdot 956/7.8}{51 + 122 + 956/7.8} \cdot 100\% = 34\%$$

OF TOTAL DESIGN LOAD.

MAX. DISPLACEMENT FROM LONG ACTING LOAD:

$0.49 \cdot 13.1 = \underline{\underline{6.4\ mm}}$

VALUE IS CALCULATED WITH THE USE OF GTSTRUDL

SHEAR REINFORCEMENT

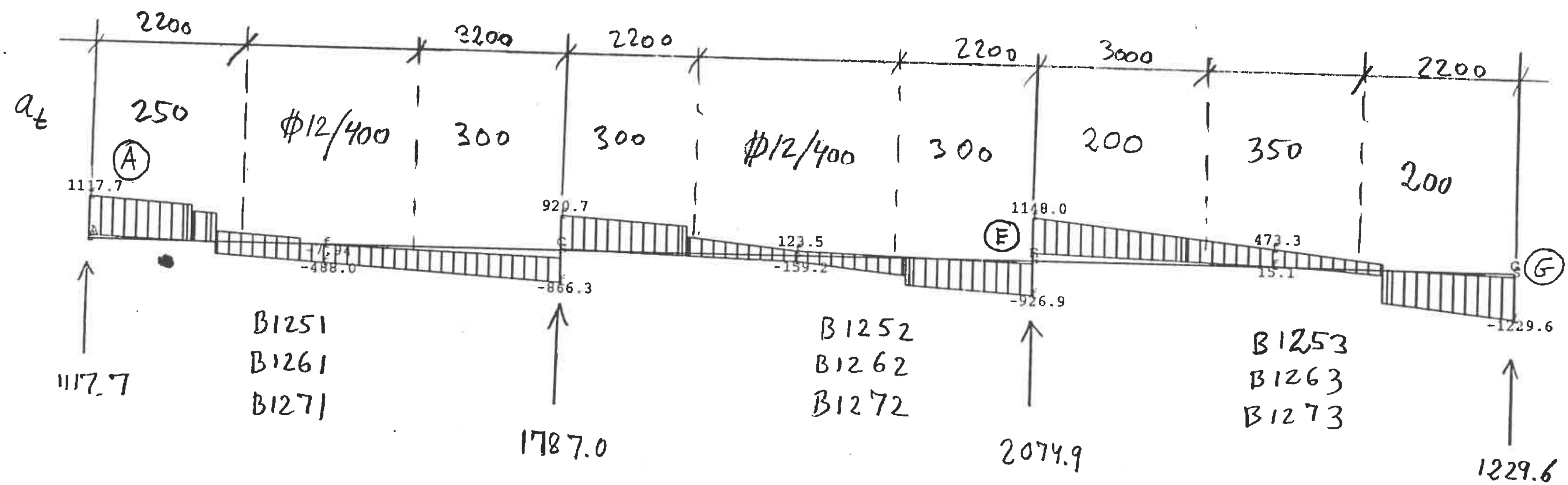
ORIENTATION

HORIZONTAL SCALE = 2.3284 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0

Φ16, 4 SECTIONS EXCEPT WHERE NOTED



SHEAR FORCE ENV. - SEC. BEAM LEVEL 1, LINE D+4300,E+1950,F-400

4.1-68

7.1-69

SHEAR CALCULATION acc. to polish standard SUPPORT A, RIGHT

STIRRUPS

Bar diameter, d_s			=	16 mm
No. of sections	=		=	4
F_s	=		=	804 mm^2
gam_f0	=		=	1,2
sigma_p	=	(VALUE TAKEN FROM TABLE 12 IN PN-84/B-3264)	=	387 N/mm^2
sigma_ps	=	sigma_p/sqrt(0.1*d_s)	=	306 N/mm^2
sigma_max	=	0,8*R_as**R_b*b_b*h_0/(2.4*gam_f0*Q_1)	=	764 N/mm^2
		sigma_ps < sigma_max, OK		

Q_1	=		=	1118 kN
Q_min	=	0.75*R_bz*b_b*h_0	=	554 kN
Q_max	=	0,25*R_b*b_b*h_0	=	2747 kN
		> Q_1, OK		
q	=		=	97 kN/m
SUM_Ni	=		=	0 kN
	(SUM_Ni is sum of konc. loads between Q_1 and Q_min)			
c_0	=	(Q_1-Q_MIN-SUM_Ni)/q	=	5,812 m
		c_0 > h_0 , Q_2,Q_3 ... COULD BE GIVEN !!!		
c_01	=	(IF c_0 < h_0 THEN c_01 = c_0)	=	2,11 m
T_1	=	Q_1*c_01/h_0	=	2203 kN
n_s	=	T_1/(gam_f0*sigma_ps*F_s)	=	8
a_t	=	c_01/n_s	=	264 mm
fi_min	=	0,2*R_bzk/0,8*R_ak	=	0,105 %
a_t,min,1	=	F_s/(fi_min*b_b)	=	1271 mm
			or	
a_t,min,2	=	0,7*h	=	805 mm
a_t,min	=	MIN(a_t,min,1 ; a_t,min,2)	=	805 mm
		> a_t, OK		

4.1-70

SHEAR CALCULATION acc. to polish standard SUPPORT G, LEFT

STIRRUPS				
Bar diameter, d_s			=	16 mm
No. of sections	=		=	4
F_s	=		=	804 mm^2
gam_f0	=		=	1,2
sigma_p	=	(VALUE TAKEN FROM TABLE 12 IN PN-84/B-3264)	=	387 N/mm^2
sigma_ps	=	sigma_p/sqrt(0.1*d_s)	=	306 N/mm^2
sigma_max	=	0,8*R_as**R_b*b_b*h_0/(2.4*gam_f0*Q_1)	=	695 N/mm^2
		sigma_ps < sigma_max, OK		

Q_1	=		=	1230 kN
Q_min	=	0.75*R_bz*b_b*h_0	=	554 kN
Q_max	=	0,25*R_b*b_b*h_0	=	2747 kN
		> Q_1, OK		
q	=		=	173 kN/m
SUM_Ni	=		=	0 kN
	(SUM_Ni is sum of konc. loads between Q_1 and Q_min)			
c_0	=	(Q_1-Q_MIN-SUM_Ni)/q	=	3,906 m
		c_0 > h_0 , Q_2,Q_3 ... COULD BE GIVEN !!!		
c_01	=	(IF c_0 < h_0 THEN c_01 = c_0)	=	2,11 m
T_1	=	Q_1*c_01/h_0	=	2423 kN
n_s	=	T_1/(gam_f0*sigma_ps*F_s)	=	9
a_t	=	c_01/n_s	=	234 mm
fi_min	=	0,2*R_bzk/0,8*R_ak	=	0,105 %
a_t,min,1	=	F_s/(fi_min*b_b)	=	1271 mm
			or	
a_t,min,2	=	0,7*h	=	805 mm
a_t,min	=	MIN(a_t,min,1 ; a_t,min,2)	=	805 mm
		> a_t, OK		

4.1-71

SHEAR CALCULATION acc. to polish standard SUPPORT E, LEFT

STIRRUPS				
Bar diameter, d_s			=	16 mm
No. of sections	=		=	4
F_s	=		=	804 mm^2
gam_f0	=		=	1,2
sigma_p	=	(VALUE TAKEN FROM TABLE 12 IN PN-84/B-3264)	=	387 N/mm^2
sigma_ps	=	sigma_p/sqrt(0.1*d_s)	=	306 N/mm^2
sigma_max	=	0,8*R_as**R_b*b_b*h_0/(2.4*gam_f0*Q_1)	=	922 N/mm^2
		sigma_ps < sigma_max, OK		
Q_1	=		=	927 kN
Q_min	=	0.75*R_bz*b_b*h_0	=	554 kN
Q_max	=	0,25*R_b*b_b*h_0	=	2747 kN
		> Q_1, OK		
q	=		=	173 kN/m
SUM_Ni	=		=	0 kN
		(SUM_Ni is sum of konc. loads between Q_1 and Q_min)		
c_0	=	(Q_1-Q_MIN-SUM_Ni)/q	=	2,155 m
		c_0 > h_0 , Q_2,Q_3 ... COULD BE GIVEN !!!		
c_01	=	(IF c_0 < h_0 THEN c_01 = c_0)	=	2,155 m
T_1	=	Q_1*c_01/h_0	=	1865 kN
n_s	=	T_1/(gam_f0*sigma_ps*F_s)	=	7
a_t	=	c_01/n_s	=	308 mm
fi_min	=	0,2*R_bzk/0,8*R_ak	=	0,105 %
a_t,min,1	=	F_s/(fi_min*b_b)	=	1271 mm
				or
a_t,min,2	=	0,7*h	=	805 mm
a_t,min	=	MIN(a_t,min,1 ; a_t,min,2)	=	805 mm
		> a_t, OK		

Sag / Case	Udført / Made	Godkendt / Approved	Dato / Date	Side / Page
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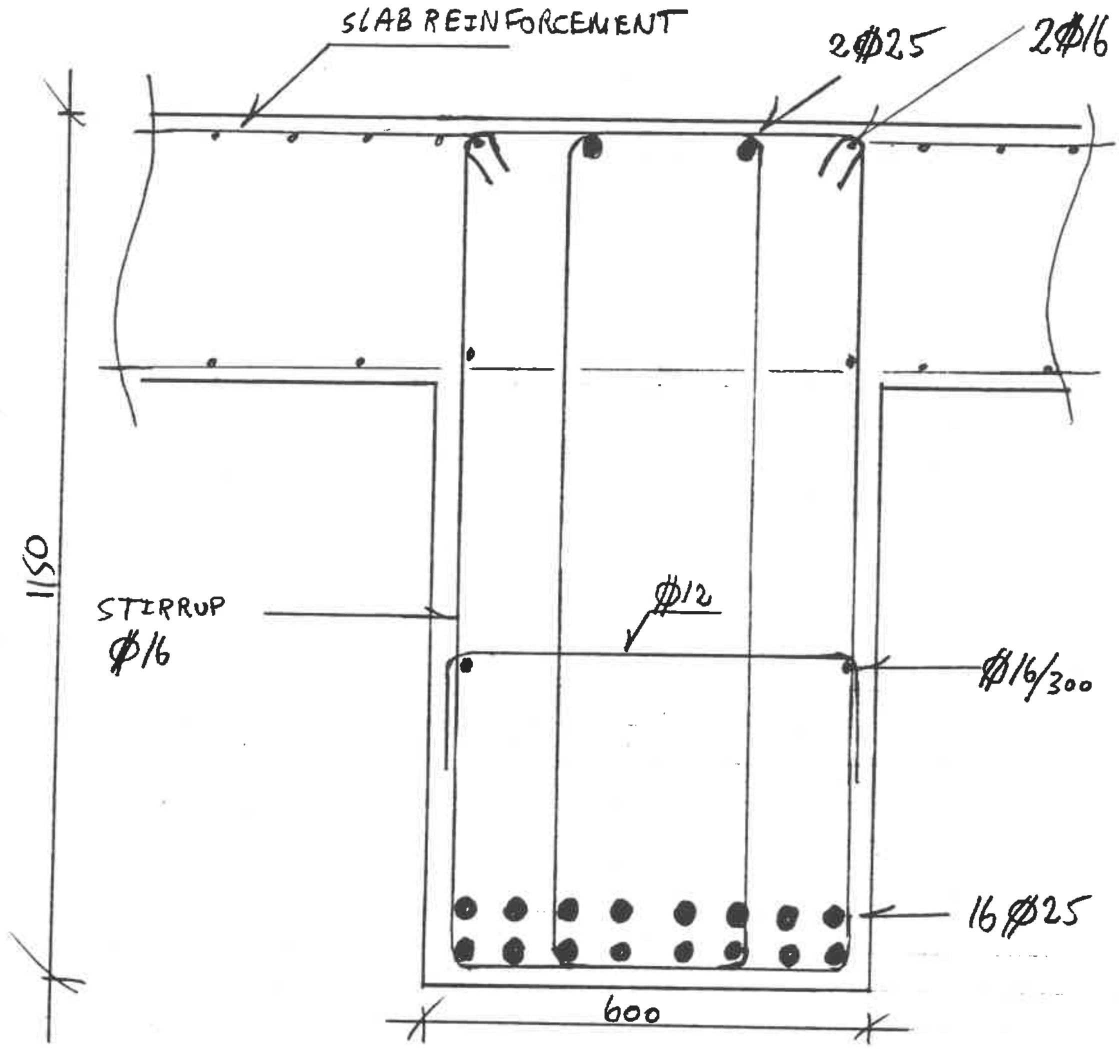
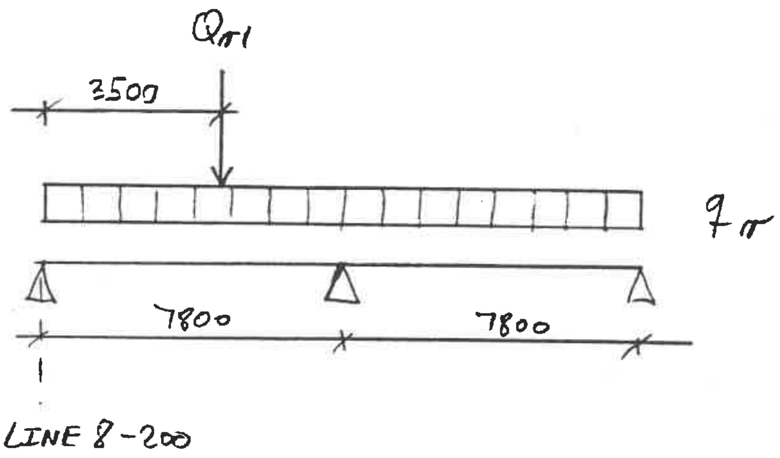
REINFORCEMENT AT MIDSPAN IN B1263



COVER 20 mm, +5/-0 mm

4.1.5.5 B1281, B1282

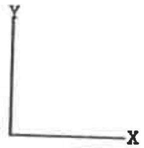


CROSS SECTION AS FOR B1261, B1262, B1263

q_T :	TOTAL DEAD LOAD	= 51 kN/m
	TOTAL LIVE LOAD	= 46 kN/m
		97 kN/m
Q_{T1} :	TOTAL LIVE LOAD	= 308 kN

REINFORCEMENT : REFER PREVIOUS CALCULATIONS

ORIENTATION



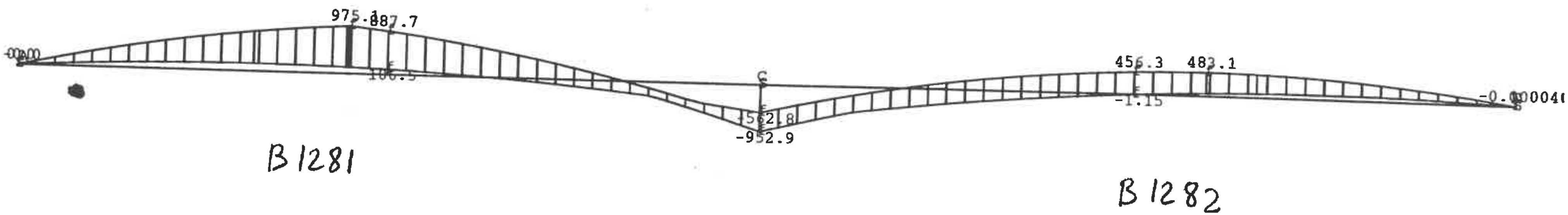
MOMENT ENVELOPE

HORIZONTAL SCALE = 1.5522 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0

NOS. OF LOAD COMB. = 3



MOMENT ENV. - SEC. BEAM LEVEL 1, LINE F+3850

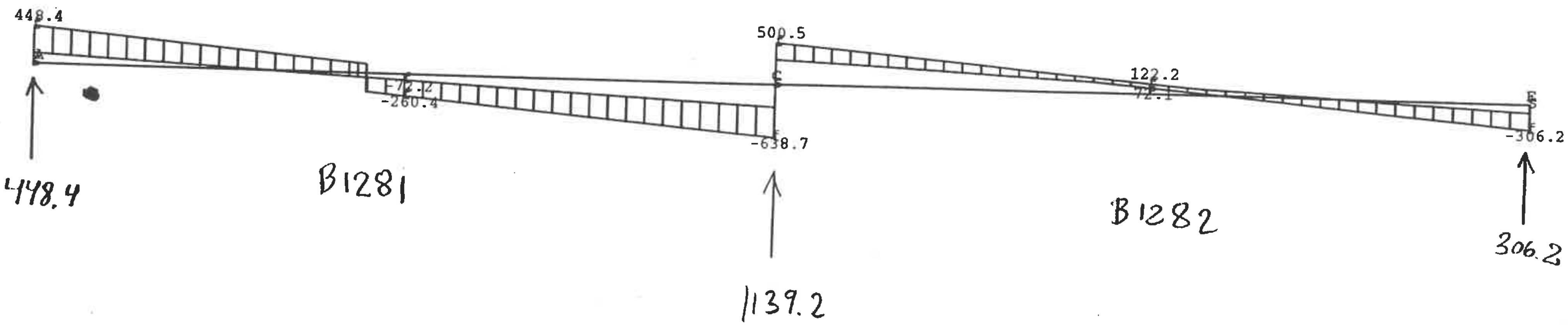
SHEAR FORCE ENVELOPE

ORIENTATION

HORIZONTAL SCALE = 1.5522 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

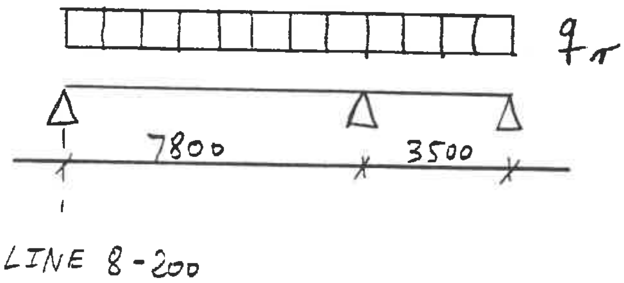
EQUIVALENT ROTATION Z .0 Y .0 X .0



SHEAR FORCE ENV. - SEC. BEAM LEVEL 1, LINE F+3850

4.1-75

4.1.5.6 B1291, B1292

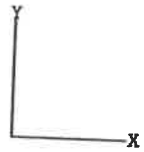


CROSS SECTION IS THE SAME AS FOR B1261, B1262, B1263

q_r :	TOTAL DEAD LOAD	=	33 kN/m
	LIVE LOAD	=	46 kN/m
			78 kN/m

REINFORCEMENT : REFER PREVIOUS CALCULATIONS

ORIENTATION



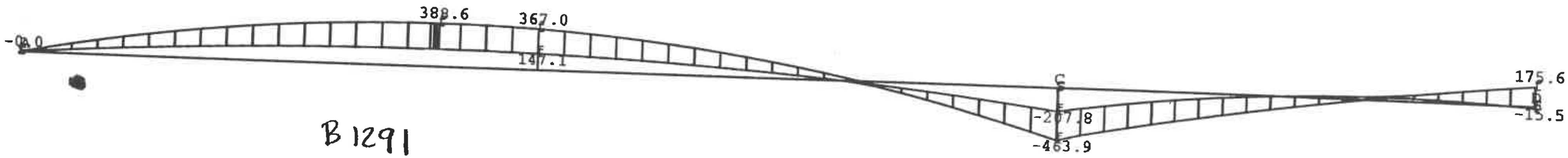
MOMENT ENVELOPE

HORIZONTAL SCALE = 1.1244 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0

NOS. OF LOAD COMB = 3

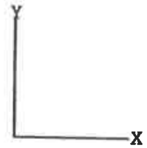


MOMENT ENV. - SEC. BEAM LEVEL 1, LINE H

4.1-77

SHEAR FORCE ENVELOPE

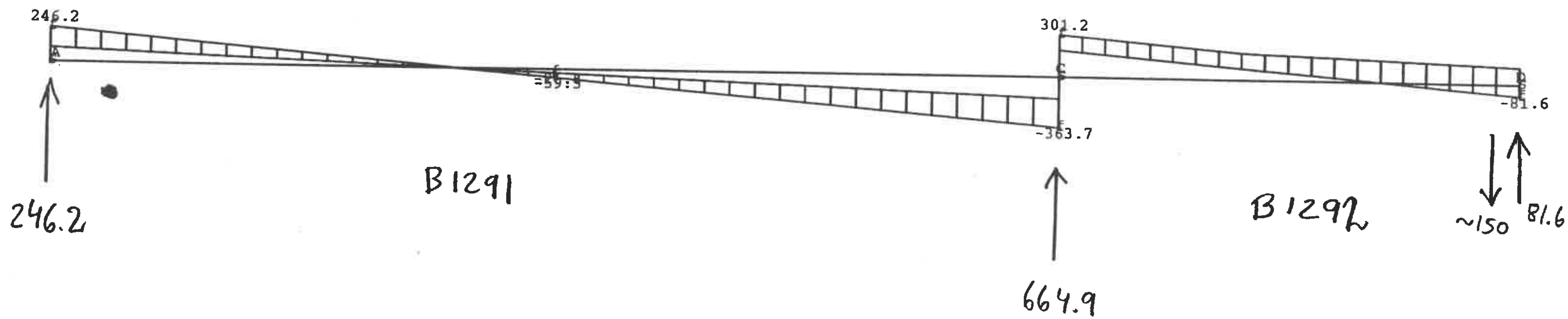
ORIENTATION



HORIZONTAL SCALE = 1.1244 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0

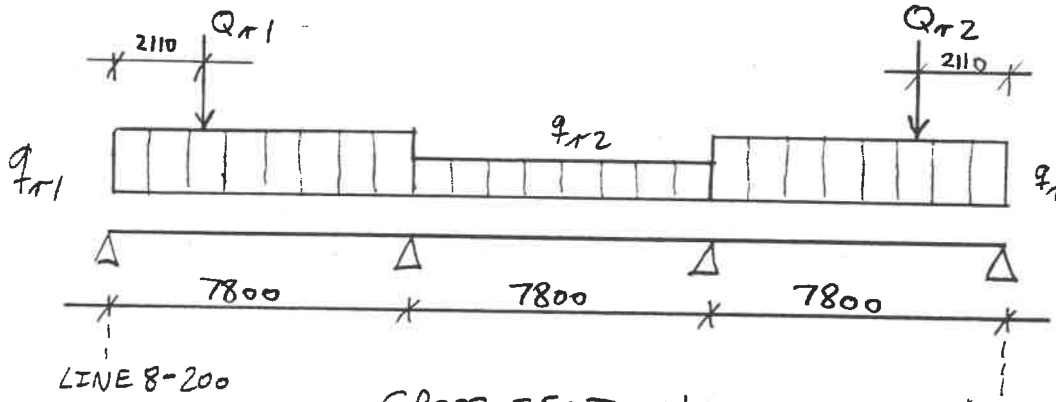


SHEAR FORCE ENV. - SEC. BEAM LEVEL 1, LINE H

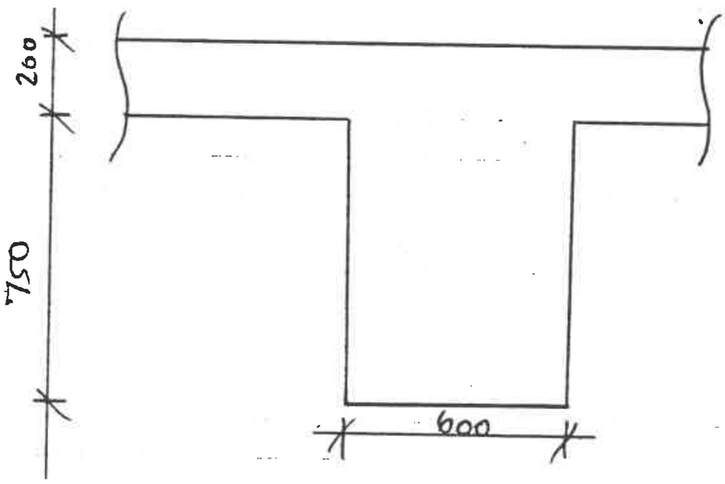
4.1-78

4.1.5.7 B1241, B1242, B1243

(B1231, B1232, B1233 REINFORCED IN THE SAME WAY)



CROSS SECTION



DEAD LOAD FROM BEAM :

$0.75 \cdot 0.6 \cdot 25 \cdot 1.1 \qquad = 12.4 \text{ kN/m}$

LINE LOAD FROM ADJACENT SLABS :

q_{r1} : DEAD LOAD $\frac{5.5}{23} \cdot 47.9 \cdot 2 \qquad = 23 \text{ kN/m}$

LIVE LOAD $\frac{10.4}{23} \cdot 47.9 \cdot 2) + 9 \qquad = 52 \text{ kN/m}$

75 kN/m

? ?

$5{,}5 \cdot 4{,}85 \cdot \frac{(0{,}5 \cdot 4{,}25 + 4{,}55)}{7{,}8} = 22{,}82 \text{ kN/m}$

q_{r2}: DEAD LOAD = 23 kN/m

LIVE LOAD $\frac{6.5}{23} \cdot 47.9 \cdot 2$ = 27 kN/m

50 kN/m

Q_{r1}: TOTAL LIVELOAD = 941 kN

Q_{r2}: TOTAL LIVE LOAD = 1360 kN

q_{r1}:	TOTAL DEAD LOAD	=	36 kN
	TOTAL LIVE LOAD	=	52 kN
			88 kN
q_{r2}:	TOTAL DEAD LOAD	=	36 kN
	TOTAL LIVE LOAD	=	27 kN
			63 kN
Q_{r1}:	TOTAL LIVE LOAD	=	941 kN
Q_{r2}:	TOTAL LIVE LOAD	=	1360 kN

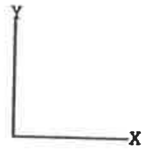
BENDING REINFORCEMENT

TABLE BELOW SHOWS ALLOWABLE MOMENTS IN CROSS SECTION, WITH RESPECT TO ULTIMATE LOAD CAPACITY AND CRACK WIDTH.

No. Ø32 (TOP/BOTTOM)	MAX. MOMENT [kNm]
14	> 2361
12	1900
10	1600
8	1221
6	1000
4	500
2	250

MOMENT ENVELOPE

ORIENTATION

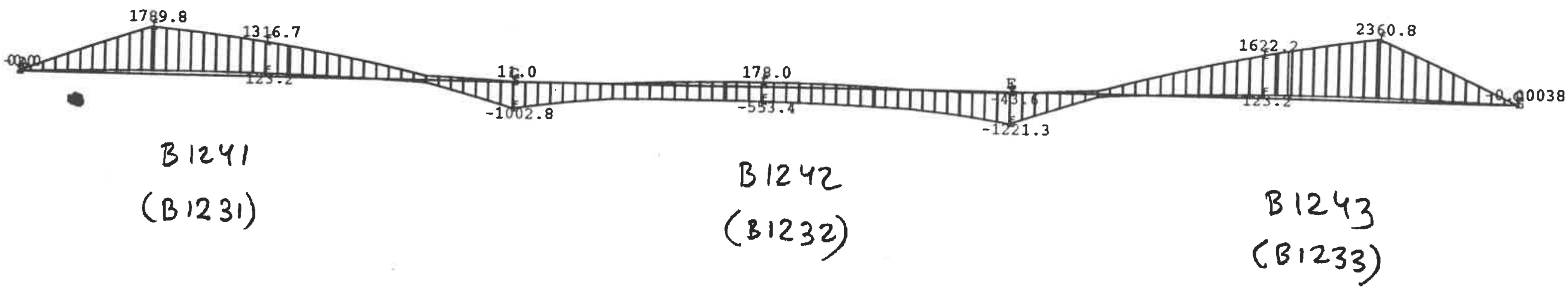


HORIZONTAL SCALE = 2.3284 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0

NOS. OF LOAD COMB. = 7



MOMENT ENV. - SEC. BEAM LEVEL 1, LINE D-1150

4.1-82

4.1-83

SHEET A

T-SHAPED BEAM
SECONDARY BEAM
1. LEVEL B1243, AT MIDSPAN

GEOMETRY				
Height, h	=		=	950 mm
Width top., b_t	=		=	1.600 mm
Width bot., b_b	=		=	600 mm
Flange thick., t	=		=	200 mm
Cover layer, c	=		=	89 mm
Eff. height, h_0	=	h -c	=	861 mm
Length, l	=		=	7,8 m
REINFORCEMENT				
No. of bars	=		=	14 pcs. } BOTTOM
Bar diameter	=		=	32 mm }
F_a	=		=	11259 mm^2
fi (T-beam)	=	F_a / (h * b_f) = F_a / (h * (b_b + 2*t))	=	1,19 %
		>fi_min OK		
fi (rect. beam)	=	F_a / (h * b_b)	=	1,98 %
		>fi_min OK		
MATERIALS				
R_b	=		=	17,1 MPa
R_bk	=		=	22,2 MPa
R_bzk	=		=	1,7 MPa
R_bz	=		=	1,2 MPa
R_a	=		=	350 MPa
R_ak	=		=	410 MPa
n_short time	=		=	6,48
n_long time	=		=	33,00
E-ak	=		=	210.000 MPa
E_b	=		=	32.400 MPa
fi_min	=	0,45 *R_bzk /R_ak	=	0,19 %
LOADS				
M_ult	=		=	2361 kNm
M_k (short time)	=	(50% live load, characteristic load)	=	850 kNm
M_d (long time)	=	(50% live load + 100% dead load, characteristic load)	=	1110 kNm
kap_f	=	1+0,5*(M_k/(M_k+M_d))	=	1,22
M_c	=	M_k+kap_f*M_d	=	2.201 kNm
ULTIMATE LOAD BEARING CAPACITY		acc. to ds 411		
omega_bal	=		=	0,50
omega	=	(F_a*R_a)/(b_t*h_0*R_b)	=	0,1673
		< omega_bal OK		
my	=	(1-½*omega)*omega	=	0,1533
beta	=	1,25 * omega	=	0,2091
h_c	=	beta * h_0	=	180,0 mm
		<1,33 * t OK		
M_u,d (+)	=	my * b * h_0^2 * R_b	=	3.109 kNm
		>M_ult		Load bearing capacity OK
"Safety"	=	M_u,d(+) / M_ult	=	1,32
ULTIMATE LOAD BEARING CAPACITY		acc. to polish standard		
X	=	(R_a*F_a)/(b_t*R_b)	=	144,04 mm
psi	=	X/h_0	=	0,17 <psi_gr, OK
psi_gr	=		=	0,50
M_ud	=	R_a*F_a*(h_0 - 0.5*X)	=	3109 KNm
		>M_ult		Load bearing capacity OK
"Safety"	=	M_u,d(+) / M_ult	=	1,32

4.1-84

METHODE B:
ELASTIC ANALYSIS

SHORT TIME		DS 411		
fi	=	F_a / b_t /h_0	=	0,0082
n * fi	=		=	0,053
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)	=	0,277
y_0	=	beta * h_0	=	238 mm
		<1,25 * t, OK		
fi_b	=	beta/6*(3-beta)	=	0,126
gamma	=	(1 - beta) / beta	=	2,613
sigma_c, max	=	M_k / (fi_b*b_t*h_0^2)	=	5,7 MPa
sigma_a, max	=	n * gamma * sigma_c,max	=	97 MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)	=	238 mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5	=	0,07 mm (CRACK WIDTH)
u_0	=	n * sigma_a,max * l^2 / (10 * y_0 * E_ak)	=	4,5 mm (DEFLECTION)
l / u_0	=		=	1.736

LONG TIME		DS 411		
fi	=	F_a / b_t /h_0	=	0,0082
n * fi	=		=	0,270
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)	=	0,513
y_0	=	beta * h_0	=	441
		<1,25 * t, OK		
fi_b	=	beta/6*(3-beta)	=	0,213
rho	=	beta*fi_b	=	0,109
I_zt	=	rho*b_t*h_0^3	=	1,11E+11 mm^4
gamma	=	(1 - beta) / beta	=	0,950
sigma_c, max	=	M_d / (fi_b*b_t*h_0^2)	=	4,4 MPa
sigma_a, max	=	n * gamma * sigma_c,max	=	138 MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)	=	238 mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5	=	0,11 mm
u_0	=	n * sigma_c,max * l^2 / (10 * y_0 * E_ak)	=	9,5 mm
l / u_0	=		=	818

Crackwidth acc. to Polish standard

gam_a	=		=	0,00
gam_b	=	(b_t-b_b)*t/(b_b*h_0)	=	0,387
L	=	M_c/(R_bk*b_b*h_0^2)	=	0,22
G	=	gam_b*(1-t/(2*h_0))+gam_a*(1-a/h_0)	=	0,342
my_a	=	F_a/(b_b*h_0)	=	0,022
psi_f	=	1/(1,8+(1+5*(L+G))/(10*n*my_a))	=	0,222
		< t'/h_0 , OK !		
Z_f	=	FORMULA (Z5-9)	=	763 mm
sigma_a	=	M_c/(Z_f*F__a)	=	256 MPa
n	=	E_ak/E_b	=	6,48
delta_1	=	(b_t-b_b)*t/(b_b*h)	=	0,35
M_fp	=	[0,292+1,5*n/(b_b*h)*(F_a+0,1*F_ac)+0,15*delta_1]*b_b*h^2*R_bzk	=	503 kNm
psi_a	=	1,3-0,8*M_fp/M_c	=	1,000
K_1	=	M_fp/(Z_f*n*F_a*R_bzk) - 2	=	3,22
l_f	=	K_1*n*F_a/(sum u_a)*n_f	=	117 mm
a_sr	=	psi_a*(sigma_a/E_ak)*l_f	=	0,143
k_f	=		=	1,536
a_f	=	k_f*a_sr	=	0,219 mm
		<0,3 mm, OK		

4.1-85

T-SHAPED BEAM
SECONDARY BEAM
1. LEVEL B1243, AT SUPPORT

SHEET A

GEOMETRY

Height, h	=		=	950 mm
Width top., b_t	=		=	600 mm
Width bot., b_b	=		=	600 mm
Flange thick., t	=		=	200 mm
Cover layer, c	=		=	89 mm
Eff. height, h_0	=	h -c	=	861 mm
Length, l	=		=	7,8 m

REINFORCEMENT

No. of bars	=			=	8 pcs. } TOP
Bar diameter	=			=	32 mm }
F_a	=			=	6434 mm^2
fi (T-beam)	=	F_a / (h * b_f) = F_a / (h * (b_b + 2*t))	>fi_min OK	=	0,68 %
fi (rect. beam)	=	F_a / (h * b_b)	>fi_min OK	=	1,13 %

MATERIALS

R_b	=		=	17,1 MPa
R_bk	=		=	22,2 MPa
R_bzk	=		=	1,7 MPa
R_bz	=		=	1,2 MPa
R_a	=		=	350 MPa
R_ak	=		=	410 MPa
n_short time	=		=	6,48
n_long time	=		=	33,00
E-ak	=		=	210.000 MPa
E_b	=		=	32.400 MPa
fi_min	=	0,45 *R_bzk /R_ak	=	0,19 %

LOADS

M_ult	=		=	1221 kNm
M_k (short time)	=	(50% live load, characteristic load)	=	440 kNm
M_d (long time)	=	(50% live load + 100% dead load, characteristic load)	=	574 kNm
kap_f	=	1+0,5*(M_k/(M_k+M_d))	=	1,22
M_c	=	M_k+kap_f*M_d	=	1.139 kNm

ULTIMATE LOAD BEARING CAPACITY acc. to ds 411

omega_bal	=			=	0,50
omega	=	(F_a*R_a)/(b_t*h_0*R_b)	< omega_bal OK	=	0,2549
my	=	(1-½*omega)*omega		=	0,2224
beta	=	1,25 * omega		=	0,3186
h_c	=	beta * h_0	~~=>1,33 * t NOT OK~~	=	274,4 mm
M_u,d (+)	=	my * b * h_0^2 * R_b	>M_ult	=	1.692 kNm Load bearing capacity OK
"Safety"	=	M_u,d(+) / M_ult		=	1,39

ULTIMATE LOAD BEARING CAPACITY acc. to polish standard

X	=	(R_a*F_a)/(b_t*R_b)		=	219,48 mm
psi	=	X/h_0		=	0,25 <psi_gr, OK
psi_gr	=			=	0,50
M_ud	=	R_a*F_a*(h_0 - 0.5*X)	>M_ult	=	1692 KNm Load bearing capacity OK
"Safety"	=	M_u,d(+) / M_ult		=	1,39

22.02.96

4.1-86

METHODE B:
ELASTIC ANALYSIS

SHORT TIME

		DS 411		
fi	=	F_a / b_t / h_0	=	0,0125
n * fi	=		=	0,081
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)	=	0,329
y_0	=	beta * h_0	=	283 mm
		~~>1,25 * t, NOT OK~~		
fi_b	=	beta/6*(3-beta)	=	0,147
gamma	=	(1 - beta) / beta	=	2,039
sigma_c, max	=	M_k / (fi_b*b_t*h_0^2)	=	6,8 MPa
sigma_a, max	=	n * gamma * sigma_c,max	=	89 MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)	=	417 mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5	=	0,09 mm (CRACK WIDTH)
u_0	=	n * sigma_a,max * l^2 / (10 * y_0 * E_ak)	=	4,5 mm (DEFLECTION)
l / u_0	=		=	1.743

LONG TIME

		DS 411		
fi	=	F_a / b_t / h_0	=	0,0125
n * fi	=		=	0,411
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)	=	0,584
y_0	=	beta * h_0	=	503
		<1,25 * t, OK		
fi_b	=	beta/6*(3-beta)	=	0,235
rho	=	beta*fi_b	=	0,138
I_zt	=	rho*b_t*h_0^3	=	5,27E+10 mm^4
gamma	=	(1 - beta) / beta	=	0,711
sigma_c, max	=	M_d / (fi_b*b_t*h_0^2)	=	5,5 MPa
sigma_a, max	=	n * gamma * sigma_c,max	=	129 MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)	=	417 mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5	=	0,13 mm
u_0	=	n * sigma_c,max * l^2 / (10 * y_0 * E_ak)	=	10,4 mm
l / u_0	=		=	749

Crackwidth acc. to Polish standard

gam_a	=		=	0,00
gam_b	=	(b_t-b_b)*t/(b_b*h_0)	=	0,000
L	=	M_c/(R_bk*b_b*h_0^2)	=	0,12
G	=	gam_b*(1-t/(2*h_0))+gam_a*(1-a/h_0)	=	0,000
my_a	=	F_a/(b_b*h_0)	=	0,012
psi_f	=	1/(1,8+(1+5*(L+G))/(10*n*my_a))	=	0,266
		~~>t/h_0, NOT OK!~~		
Z_f	=	FORMULA (Z5-9)	=	746 mm
sigma_a	=	M_c/(Z_f*F__a)	=	237 MPa

n	=	E_ak/E_b	=	6,48
delta_1	=	(b_t-b_b)*t/(b_b*h)	=	0,00
M_fp	=	[0,292+1,5*n/(b_b*h)*(F_a+0,1*F_ac)+0,15*delta_1]*b_b*h^2*R_bzk	=	376 kNm
psi_a	=	1,3-0,8*M_fp/M_c	=	1,000
K_1	=	M_fp/(Z_f*n*F_a*R_bzk) - 2	=	4,99
l_f	=	K_1*n*F_a/(sum u_a)*n_f	=	181 mm
a_sr	=	psi_a*(sigma_a/E_ak)*l_f	=	0,205
k_f	=		=	1,227
a_f	=	k_f*a_sr	=	0,251 mm

<0,3 mm, OK

h:\95115\123\beam

CALCULATION OF DEFLECTION

B1243

TRANSFORMED MOMENT OF INERTIA (REF. SPREAD-SHEET):

$I_{zt} = 5.27 \cdot 10^{10}$ mm^4 (AT SUPPORT)

$I_{zt} = 1.11 \cdot 10^{11}$ mm^4 (AT MIDSPAN)

VALUE USED IN GTSTRUDL MODEL:

$I_{zt} = 8.2 \cdot 10^{10}$ mm^4

LONG ACTING LOAD : (DEAD LOAD + 50% LIVE LOAD)

$$\sim \frac{1}{1.2} \cdot \frac{36 + 0.5 \cdot 52 + 0.5 \cdot 1360/7.8}{36 + 52 + 1360/7.8} \cdot 100\% = 47 \%$$

OF TOTAL DESIGN LOAD

$E = 6400 \; N/mm^2$

SHORT ACTING LOAD : (50% LIVE LOAD)

$$\sim \frac{1}{1.2} \cdot \frac{0.5 \cdot 52 + 0.5 \cdot 1360/7.8}{36 + 52 + 1360/7.8} \cdot 100\% = 36 \%$$

OF TOTAL DESIGN LOAD

MAX. DISPLACEMENT FROM LONG ACTING LOAD:

$0.47 \cdot 19.3 = 9.1$ mm

THIS VALUE IS CALCULATED WITH THE USE OF GTSTRUDL.

4.1-88

SHEAR REINFORCEMENT

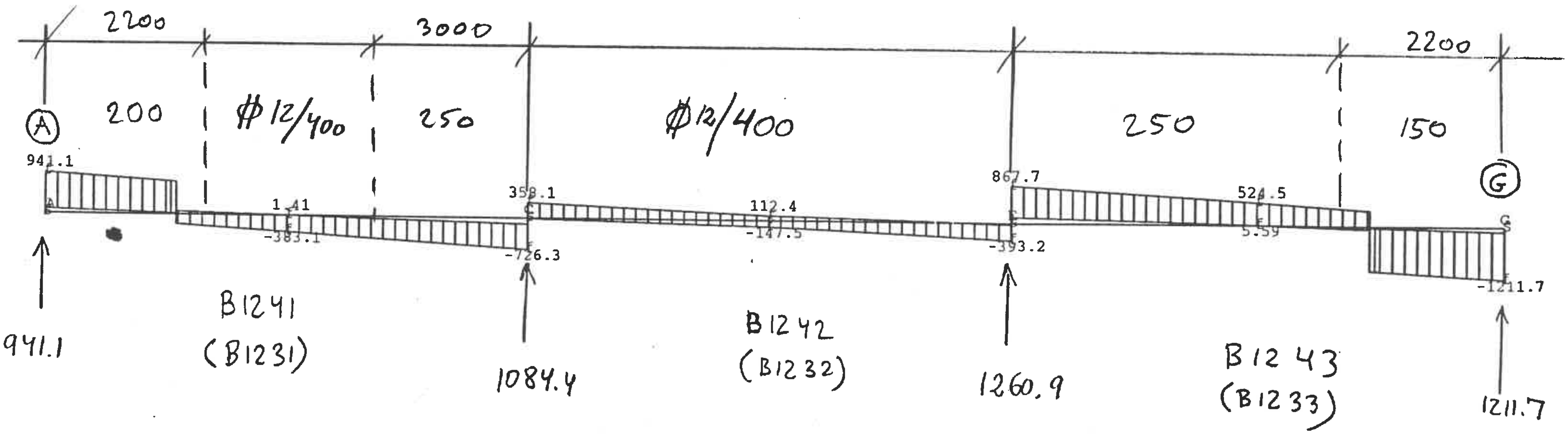
ORIENTATION

HORIZONTAL SCALE = 2.3284 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0

Ø16, 4 SECTIONS
EXCEPT WHERE NOTED



SHEAR FORCE ENV. - SEC. BEAM LEVEL 1, LINE D-1150

4.1-89

SHEAR CALCULATION acc. to polish standard SUPPORT G,LEFT

STIRRUPS				
Bar diameter, d_s			=	16 mm
No. of sections	=		=	4
F_s	=		=	804 mm^2
gam_f0	=		=	1,2
sigma_p	=	(VALUE TAKEN FROM TABLE 12 IN PN-84/B-3264)	=	387 N/mm^2
sigma_ps	=	sigma_p/sqrt(0.1*d_s)	=	306 N/mm^2
sigma_max	=	0,8*R_as**R_b*b_b*h_0/(2.4*gam_f0*Q_1)	=	567 N/mm^2
		sigma_ps < sigma_max, OK		

Q_1	=		=	1212 kN
Q_min	=	0.75*R_bz*b_b*h_0	=	446 kN
Q_max	=	0,25*R_b*b_b*h_0	=	2208 kN
		> Q_1, OK		
q	=		=	88 kN/m
SUM_Ni	=		=	0 kN
	(SUM_Ni is sum of konc. loads between Q_1 and Q_min)			
c_0	=	(Q_1-Q_MIN-SUM_Ni)/q	=	8,709 m
		c_0 > h_0 , Q_2,Q_3 ... COULD BE GIVEN !!!		
c_01	=	(IF c_0 < h_0 THEN c_01 = c_0)	=	2,11 m
T_1	=	Q_1*c_01/h_0	=	2970 kN
n_s	=	T_1/(gam_f0*sigma_ps*F_s)	=	11
a_t	=	c_01/n_s	=	192 mm
fi_min	=	0,2*R_bzk/0,8*R_ak	=	0,105 %
a_t,min,1	=	F_s/(fi_min*b_b)	=	1271 mm
			or	
a_t,min,2	=	0,7*h	=	665 mm
a_t,min	=	MIN(a_t,min,1 ; a_t,min,2)	=	665 mm
		> a_t, OK		

4.1-90

SHEAR CALCULATION acc. to polish standard SUPPORT A,RIGHT

STIRRUPS

Bar diameter, d_s			=	16 mm
No. of sections	=		=	4
F_s	=		=	804 mm^2
gam_f0	=		=	1,2
sigma_p	=	(VALUE TAKEN FROM TABLE 12 IN PN-84/B-3264)	=	387 N/mm^2
sigma_ps	=	sigma_p/sqrt(0.1*d_s)	=	306 N/mm^2
sigma_max	=	0,8*R_as**R_b*b_b*h_0/(2.4*gam_f0*Q_1)	=	730 N/mm^2

sigma_ps < sigma_max, OK

Q_1	=		=	941 kN
Q_min	=	0.75*R_bz*b_b*h_0	=	446 kN
Q_max	=	0,25*R_b*b_b*h_0	=	2208 kN
		> Q_1, OK		
q	=		=	88 kN/m
SUM_Ni	=		=	0 kN
		(SUM_Ni is sum of konc. loads between Q_1 and Q_min)		
c_0	=	(Q_1-Q_MIN-SUM_Ni)/q	=	5,630 m
		c_0 > h_0 , Q_2,Q_3 ... COULD BE GIVEN !!!		
c_01	=	(IF c_0 < h_0 THEN c_01 = c_0)	=	2,11 m
T_1	=	Q_1*c_01/h_0	=	2306 kN
n_s	=	T_1/(gam_f0*sigma_ps*F_s)	=	8
a_t	=	c_01/n_s	=	264 mm
fi_min	=	0,2*R_bzk/0,8*R_ak	=	0,105 %
a_t,min,1	=	F_s/(fi_min*b_b)	=	1271 mm
			or	
a_t,min,2	=	0,7*h	=	665 mm
a_t,min	=	MIN(a_t,min,1 ; a_t,min,2)	=	665 mm
		> a_t, OK		

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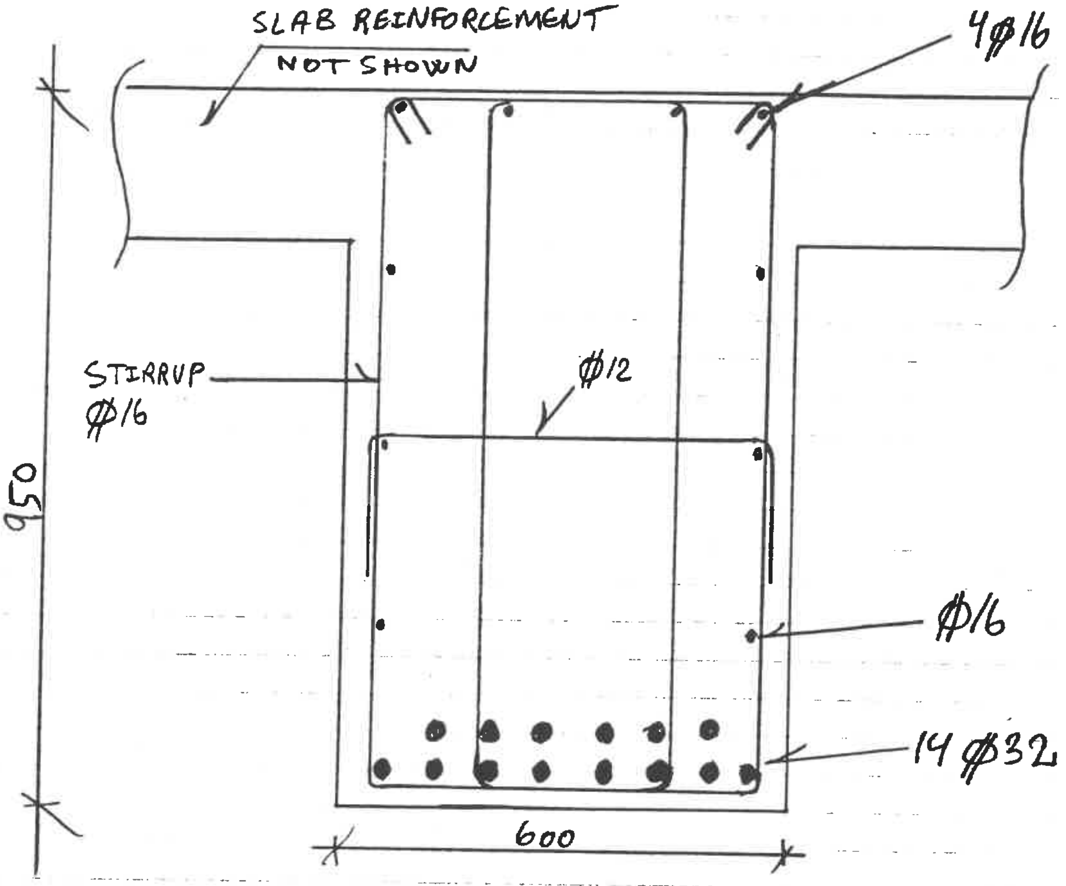
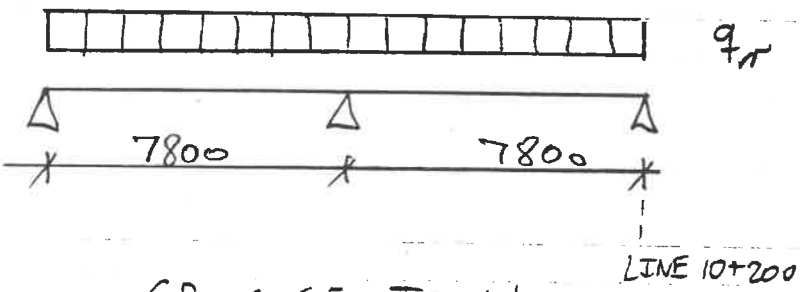
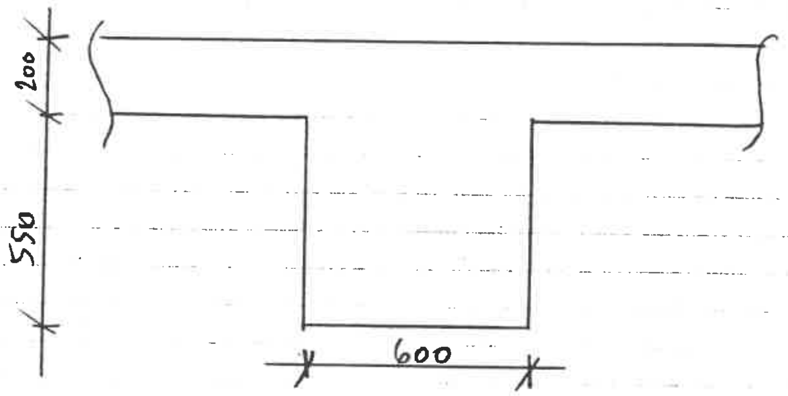
REINFORCEMENT AT MID SPAN B 1243



4.1.5.8 B 1222, B 1223



CROSS SECTION



DEAD LOAD FROM BEAM:

$0.55 \cdot 0.6 \cdot 25 \cdot 1.1 = 9.1$ kN/m

LINE LOAD FROM ADJACENT SLABS:

q_r: DEAD LOAD $\frac{5.5}{23} \cdot 47.9 \cdot 2 = 22.9$ kN/m

LIVE LOAD $\frac{10.4+6.5}{23} \cdot 47.9 = 35.2$ kN/m

58.1 kN/m

q_r: TOTAL DEAD LOAD	= 32 kN/m
TOTAL LIVE LOAD	= 35 kN/m
	67 kN/m

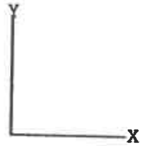
BENDING REINFORCEMENT

TABLE BELOW SHOWS ALLOWABLE MOMENTS IN CROSS SECTION, WITH RESPECT TO ULTIMATE LOAD CAPACITY AND CRACKWIDTH.

No. Ø25 (TOP/BOTTOM)	
6	> 510
4	300
2	150

MOMENT ENVELOPE

ORIENTATION

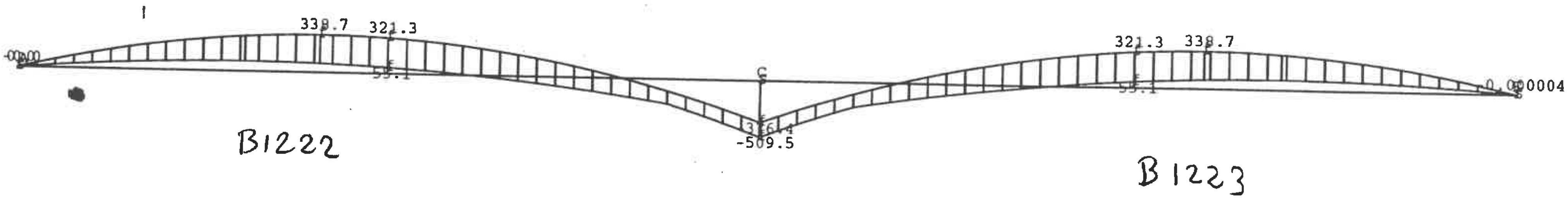


HORIZONTAL SCALE = 1.5522 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0

NOS. OF LOAD COMB. = 3



MAX. DISPLACEMENT FROM LONG ACTING LOAD ~8.5 mm

MOMENT ENV. - SEC. BEAM LEVEL 1, LINE B+2550

4.1-94

4.1-95

T-SHAPED BEAM
SECONDARY BEAM
1. LEVEL B1222, AT SUPPORT

SHEET A

GEOMETRY

Height, h	=		=	750 mm
Width top., b_t	=		=	600 mm
Width bot., b_b	=		=	600 mm
Flange thick., t	=		=	200 mm
Cover layer, c	=		=	50 mm
Eff. height, h_0	=	h -c	=	700 mm
Length, l	=		=	7,8 m

REINFORCEMENT

No. of bars	=			=	6 pcs. } top?
Bar diameter	=			=	25 mm }
F_a	=			=	2945 mm^2
fi (T-beam)	=	F_a / (h * b_f) = F_a / (h * (b_b + 2*t))	>fi_min OK	=	0,39 %
fi (rect. beam)	=	F_a / (h * b_b)	>fi_min OK	=	0,65 %

MATERIALS

R_b	=		=	17,1 MPa
R_bk	=		=	22,2 MPa
R_bzk	=		=	1,7 MPa
R_bz	=		=	1,2 MPa
R_a	=		=	350 MPa
R_ak	=		=	410 MPa
n_short time	=		=	6,48
n_long time	=		=	33,00
E-ak	=		=	210.000 MPa
E_b	=		=	32.400 MPa
fi_min	=	0,45 *R_bzk /R_ak	=	0,19 %

LOADS

M_ult	=		=	510 kNm
M_k (short time)	=	(50% live load, characteristic load)	=	107 kNm
M_d (long time)	=	(50% live load + 100% dead load, characteristic load)	=	316 kNm
kap_f	=	1+0,5*(M_k/(M_k+M_d))	=	1,13
M_c	=	M_k+kap_f*M_d	=	463 kNm

ULTIMATE LOAD BEARING CAPACITY acc. to ds 411

omega_bal	=			=	0,50
omega	=	(F_a*R_a)/(b_t*h_0*R_b)	< omega_bal OK	=	0,1435
my	=	(1-½*omega)*omega		=	0,1332
beta	=	1,25 * omega		=	0,1794
h_c	=	beta * h_0	<1,33 * t OK	=	125,6 mm
M_u,d (+)	=	my * b * h_0^2 * R_b	>M_ult	=	670 kNm
"Safety"	=	M_u,d(+) / M_ult		Load bearing capacity OK =	1,31

ULTIMATE LOAD BEARING CAPACITY acc. to polish standard

X	=	(R_a*F_a)/(b_t*R_b)		=	100,47 mm
psi	=	X/h_0		=	0,14 <psi_gr, OK
psi_gr	=			=	0,50
M_ud	=	R_a*F_a*(h_0 - 0.5*X)	>M_ult	=	670 KNm
"Safety"	=	M_u,d(+) / M_ult		Load bearing capacity OK =	1,31

4.1-96

METHODE B:
ELASTIC ANALYSIS

SHORT TIME		DS 411	
fi	=	F_a / b_t /h_0	= 0,0070
n * fi	=		= 0,045
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)	= 0,259
y_0	=	beta * h_0	= 182 mm
		<1,25 * t, OK	
fi_b	=	beta/6*(3-beta)	= 0,119
gamma	=	(1 - beta) / beta	= 2,854
sigma_c, max	=	M_k / (fi_b*b_t*h_0^2)	= 3,1 MPa
sigma_a, max	=	n * gamma * sigma_c,max	= 57 MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)	= 400 mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5	= 0,06 mm (CRACK WIDTH)
u_0	=	n * sigma_a,max * l^2 / (10 * y_0 * E_ak)	= 3,2 mm (DEFLECTION)
l / u_0	=		= 2.457

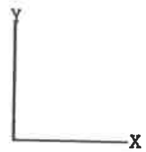
LONG TIME		DS 411	
fi	=	F_a / b_t /h_0	= 0,0070
n * fi	=		= 0,231
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)	= 0,487
y_0	=	beta * h_0	= 341
		<1,25 * t, OK	
fi_b	=	beta/6*(3-beta)	= 0,204
rho	=	beta*fi_b	= 0,099
I_zt	=	rho*b_t*h_0^3	= 2,05E+10 mm^4
gamma	=	(1 - beta) / beta	= 1,053
sigma_c, max	=	M_d / (fi_b*b_t*h_0^2)	= 5,3 MPa
sigma_a, max	=	n * gamma * sigma_c,max	= 183 MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)	= 400 mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5	= 0,18 mm
u_0	=	n * sigma_c,max * l^2 / (10 * y_0 * E_ak)	= 14,8 mm
l / u_0	=		= 528

Crackwidth acc. to Polish standard

gam_a	=		= 0,00
gam_b	=	(b_t-b_b)*t/(b_b*h_0)	= 0,000
L	=	M_c/(R_bk*b_b*h_0^2)	= 0,07
G	=	gam_b*(1-t/(2*h_0))+gam_a*(1-a/h_0)	= 0,000
my_a	=	F_a/(b_b*h_0)	= 0,007
psi_f	=	1/(1,8+(1+5*(L+G))/(10*n*my_a))	= 0,209
		< t'/h_0 , OK !	
Z_f	=	FORMULA (Z5-9)	= 627 mm
sigma_a	=	M_c/(Z_f*F__a)	= 251 MPa

n	=	E_ak/E_b	= 6,48
delta_1	=	(b_t-b_b)*t/(b_b*h)	= 0,00
M_fp	=	[0,292+1,5*n/(b_b*h)*(F_a+0,1*F_ac)+0,15*delta_1]*b_b*h^2*R_bzk	= 208 kNm
psi_a	=	1,3-0,8*M_fp/M_c	= 0,941
K_1	=	M_fp/(Z_f*n*F_a*R_bzk) - 2	= 8,03
l_f	=	K_1*n*F_a/(sum u_a)*n_f	= 228 mm
a_sr	=	psi_a*(sigma_a/E_ak)*l_f	= 0,256
k_f	=		= 1,000
a_f	=	k_f*a_sr	= 0,256 mm
		<0,3 mm, OK	

ORIENTATION



SHEAR REINFORCEMENT

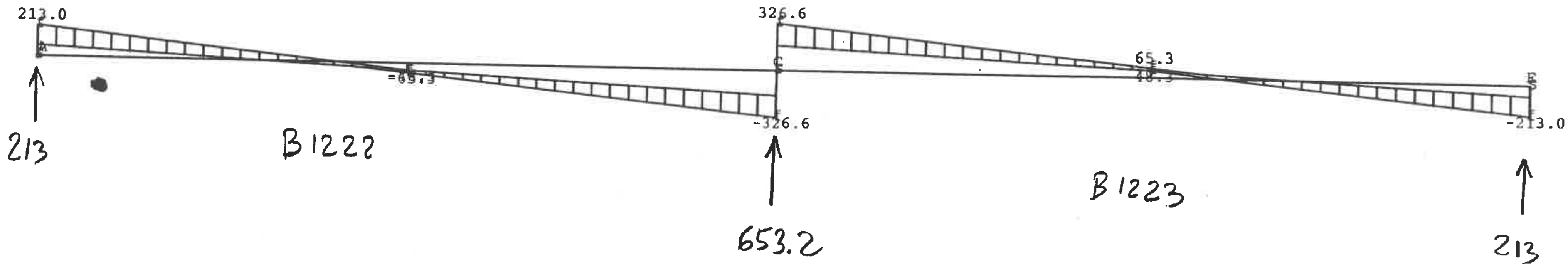
HORIZONTAL SCALE = 1.5522 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0

Ø12, 4 SECTIONS

a_t = 400 mm IN THE ENTIRE BEAM LENGTH



SHEAR FORCE ENV. - SEC. BEAM LEVEL 1, LINE B+2550

4.1-97

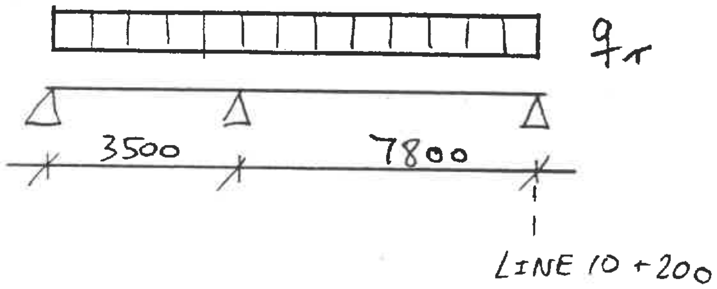
4.1-98

SHEAR CALCULATION acc. to polish standard

STIRRUPS				
Bar diameter, d_s			=	12 mm
No. of sections	=		=	4
F_s	=		=	452 mm^2
gam_f0	=		=	1,2
sigma_p	=	(VALUE TAKEN FROM TABLE 12 IN PN-84/B-3264)	=	387 N/mm^2
sigma_ps	=	sigma_p/sqrt(0.1*d_s)	=	353 N/mm^2
sigma_max	=	0,8*R_as**R_b*b_b*h_0/(2.4*gam_f0*Q_1)	=	1708 N/mm^2
		sigma_ps < sigma_max, OK		

Q_1	=		=	327 kN
Q_min	=	0.75*R_bz*b_b*h_0	=	362 kN
Q_max	=	0,25*R_b*b_b*h_0	=	1796 kN
		> Q_1, OK		
q	=		=	67 kN/m
SUM_Ni	=		=	0 kN
		(SUM_Ni is sum of konc. loads between Q_1 and Q_min)		
c_0	=	(Q_1-Q_MIN-SUM_Ni)/q	=	-0,526 m
		c_0 < h_0 , T_1 = Q_1		
c_01	=	(IF c_0 < h_0 THEN c_01 = c_0)	=	-0,526 m
T_1	=	Q_1*c_01/h_0	=	-246 kN
n_s	=	T_1/(gam_f0*sigma_ps*F_s)	=	-1
a_t	=	c_01/n_s	=	526 mm
fi_min	=	0,2*R_bzk/0,8*R_ak	=	0,105 %
a_t,min,1	=	F_s/(fi_min*b_b)	=	715 mm
		or		
a_t,min,2	=	0,7*h	=	525 mm
a_t,min	=	MIN(a_t,min,1 ; a_t,min,2)	=	525 mm
		< a_t, a_t,min is chosen		

4.1.5.9 B1212, B1213



CROSS SECTION IS THE SAME AS FOR B1222, B1223

q_r : TOTAL DEAD LOAD	=	21 kN/m
TOTAL LIVE LOAD	=	14 kN/m
		35 kN/m

REINFORCEMENT : REFER CALCULATION OF B1222 AND B1223.

MOMENT ENVELOPE

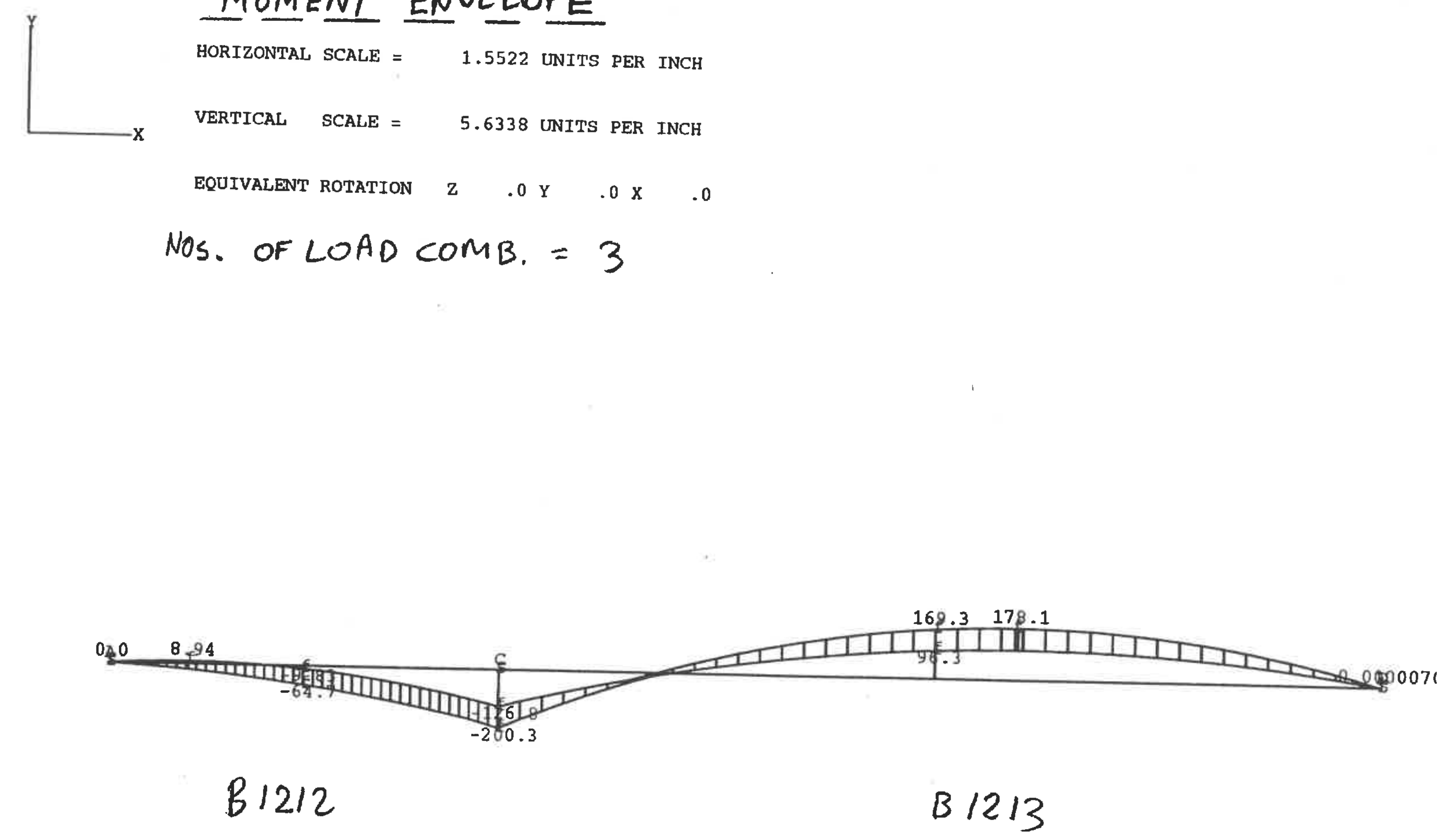
ORIENTATION

HORIZONTAL SCALE = 1.5522 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0

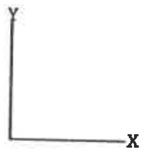
NOS. OF LOAD COMB. = 3



MOMENT ENV. - SEC. BEAM LEVEL 1, LINE A + 300

4.1-100

ORIENTATION

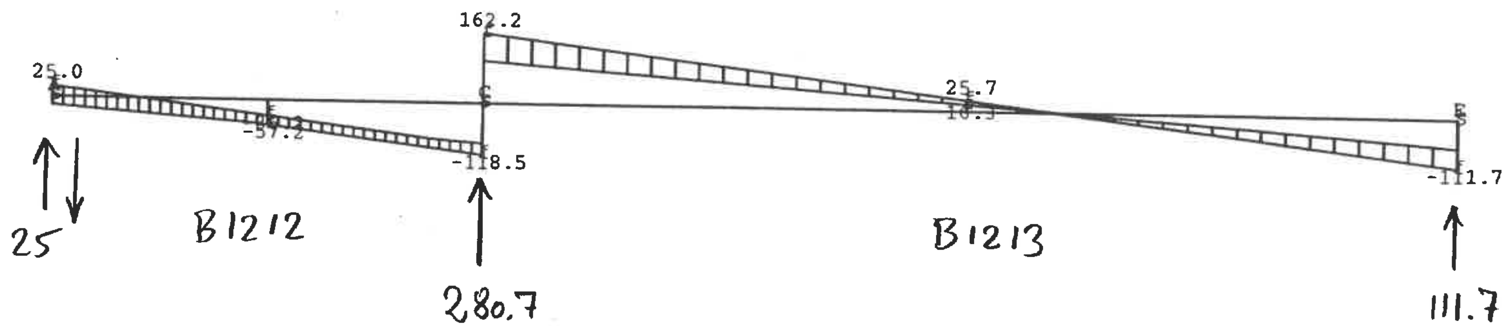


SHEAR FORCE ENVELOPE

HORIZONTAL SCALE = 1.5522 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0

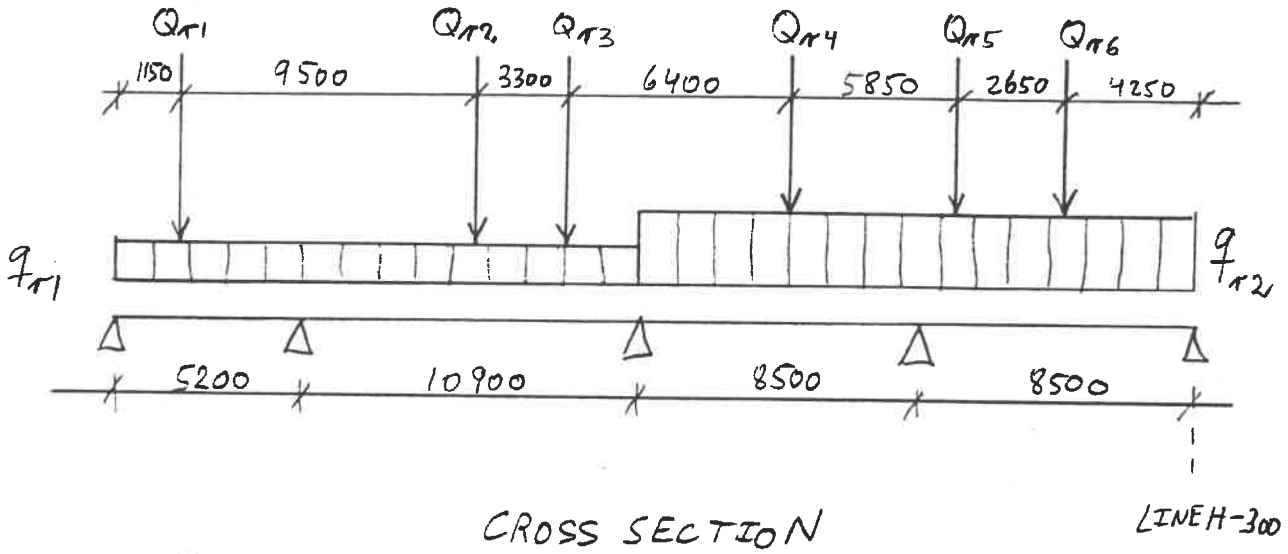


SHEAR FORCE ENV. - SEC. BEAM LEVEL 1, LINE A+300

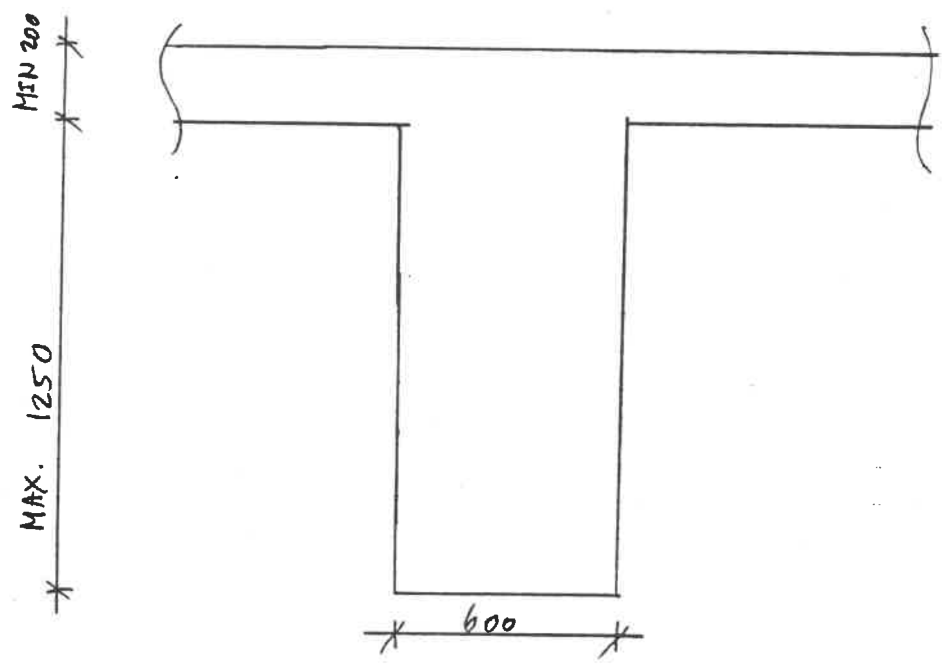
4.1-101

4.1.6 PRIMARY BEAMS

4.1.6.1 B1121, B1122, B1123, B1124



CROSS SECTION



DEAD LOAD FROM BEAM :

$1.25 \cdot 0.6 \cdot 25 \cdot 1.1 \qquad = 20.6 \text{ kN/m}$

LINE LOAD FROM ADJACENT SLABS :

$q_{\pi 1}$: DEAD LOAD $\frac{5.5}{23} \cdot 39.9 \cdot 2 = 19.1$ kN/m

LIVE LOAD $\frac{10.4+6.5}{23} \cdot 39.9 = 29.3$ kN/m

48.4 kN/m

$q_{\pi 2}$: DEAD LOAD $\frac{10.63}{120.63} \cdot 164 \cdot 2 = 28.9$ kN/m

LIVE LOAD $\frac{13}{120.63} \cdot 164 \cdot 2 = 35.3$ kN/m

64.2 kN/m

POINT LOADS :

$Q_{\pi 1}$: POINT FROM B1222.

DEAD LOAD $\frac{32}{67} \cdot 213 = 102$ kN

LIVE LOAD $\frac{35}{67} \cdot 213 = 111$ kN

213 kN

$Q_{\pi 2}$: POINT LOAD FROM B1241, B1242 + CORNER REACTIONS FROM SLABS :

DEAD LOAD $0.2 \cdot 1085 - 4 \cdot \frac{5.5}{23} \cdot 45 = 174$ kN

LIVE LOAD $0.8 \cdot 1085 - 4 \cdot \frac{(10.4+6.5)}{2 \cdot 23} 45 + 29 = 831$ kN

1005 kN

$Q_{\pi 3}$: LIVE LOAD = 29 kN

$Q_{\pi 4}$: POINT LOAD FROM B1261, B1262 + CORNER REACTIONS FROM SLABS :

DEAD LOAD $0.2 \cdot 1665 - 4 \cdot \frac{10.63}{120.63} \cdot 167 = 274$ kN

LIVE LOAD $0.8 \cdot 1665 - 4 \frac{13}{120.63} \cdot 167 = 1260$ kN

1534 kN

Q_{T5} : LIVE LOAD = 114 kN

Q_{T6} : POINT LOAD FROM B1281, B1282

DEAD LOAD 0.35 · 1139 = 399 kN

LIVE LOAD 0.65 · 1139 = 740 kN

1139 kN

q_{T1} : TOTAL DEAD LOAD = 40 kN/m

TOTAL LIVE LOAD = 29 kN/m

69 kN/m

q_{T2} : TOTAL DEAD LOAD = 50 kN/m

TOTAL LIVE LOAD = 35 kN/m

85 kN/m

Q_{T1} : TOTAL DEAD LOAD = 102 kN

TOTAL LIVE LOAD = 111 kN

213 kN

Q_{T2} : TOTAL DEAD LOAD = 174 kN

TOTAL LIVE LOAD = 831 kN

1005 kN

Q_{T3} : TOTAL LIVE LOAD = 29 kN

Q_{T4} : TOTAL DEAD LOAD = 274 kN

TOTAL LIVE LOAD = 1260 kN

1534 kN

Q_{T5} : TOTAL LIVE LOAD = 114 kN

Q_{T6} : TOTAL DEAD LOAD = 399 kN

TOTAL LIVE LOAD = 740 kN

1139 kN

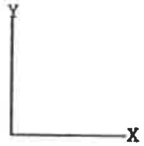
BENDING REINFORCEMENT

TABLE BELOW SHOWS ALLOWABLE MOMENTS IN CROSS SECTION, WITH RESPECT TO ULTIMATE LOAD CAPACITY AND CRACK WIDTH.

NO. Ø25 (TOP/BOTTOM)	MAX. MOMENT [kNm]
16	> 2647
14	2300
12	2000
10	1600
8	1200
6	800
4	600
2	300

MOMENT ENVELOPE

ORIENTATION

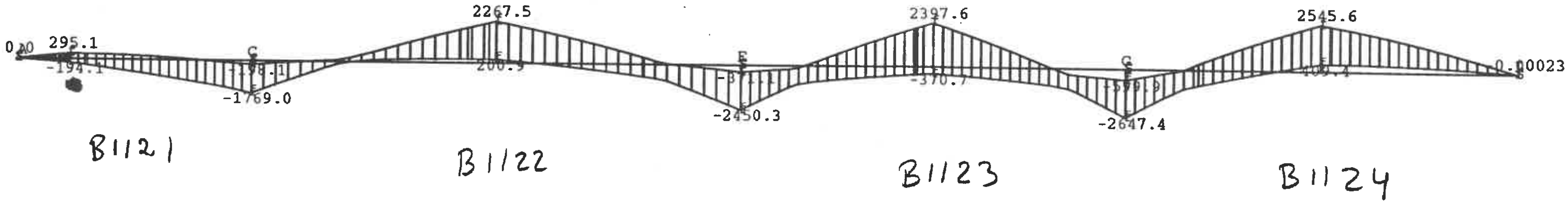


HORIZONTAL SCALE = 3.2935 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0

NOS. OF LOAD COMB. = 15



MOMENT ENV. - PRIM. BEAM LEVEL 1, LINE 9-3900

4.1 - 107

SHEET A

T-SHAPED BEAM
PRIMARY BEAM
1. LEVEL B1124, AT SUPPORT

GEOMETRY

Height, h	=				
Width top., b_t	=			=	1.450 mm
Width bot., b_b	=			=	600 mm
Flange thick., t	=			=	600 mm
Cover layer, c	=			=	200 mm
Eff. height, h_0	=	h -c		=	89 mm
Length, l	=			=	1361 mm
				=	8,5 m

REINFORCEMENT

No. of bars	=				
Bar diameter	=			=	16 pcs. } TOP
F_a	=			=	25 mm
fi (T-beam)	=	F_a / (h * b_f) = F_a / (h * (b_b + 2*t))		=	7854 mm^2
				=	0,54 %
			>fi_min OK		
fi (rect. beam)	=	F_a / (h * b_b)		=	0,90 %
			>fi_min OK		

MATERIALS

R_b	=			
R_bk	=		=	17,1 MPa
R_bzk	=		=	22,2 MPa
R_bz	=		=	1,7 MPa
R_a	=		=	1,2 MPa
R_ak	=		=	350 MPa
n_short time	=		=	410 MPa
n_long time	=		=	6,48
E-ak	=		=	33,00
E_b	=		=	210.000 MPa
fi_min	=	0,45 *R_bzk /R_ak	=	32.400 MPa
			=	0,19 %

LOADS

M_ult	=			
M_k (short time)	=	(50% live load, characteristic load)	=	2647 kNm
M_d (long time)	=	(50% live load + 100% dead load, characteristic load)	=	821 kNm
kap_f	=	1+0,5*(M_k/(M_k+M_d))	=	1376 kNm
M_c	=	M_k+kap_f*M_d	=	1,19
			=	2.454 kNm

ULTIMATE LOAD BEARING CAPACITY acc. to ds 411

omega_bal	=				
omega	=	(F_a*R_a)/(b_t*h_0*R_b)		=	0,50
				=	0,1969
			< omega_bal OK		
my	=	(1-½*omega)*omega		=	0,1775
beta	=	1,25 * omega		=	0,2461
h_c	=	beta * h_0		=	334,9 mm
			~~≤1,33 * 1 NOT OK~~		
M_u,d (+)	=	my * b * h_0^2 * R_b		=	3.373 kNm
			>M_ult		Load bearing capacity OK
"Safety"	=	M_u,d(+) / M_ult		=	1,27

ULTIMATE LOAD BEARING CAPACITY acc. to polish standard

X	=	(R_a*F_a)/(b_t*R_b)			
psi	=	X/h_0		=	267,92 mm
psi_gr	=			=	0,20 <psi_gr, OK
M_ud	=	R_a*F_a*(h_0 - 0.5*X)		=	0,50
				=	3373 KNm
			>M_ult		Load bearing capacity OK
"Safety"	=	M_u,d(+) / M_ult		=	1,27

4, 1 - 108

METHODE B:
ELASTIC ANALYSIS

SHORT TIME — DS 411

fi	=	F_a / b_t /h_0	=	0,0096
n * fi	=		=	0,062
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)	=	0,296
y_0	=	beta * h_0	=	403 mm
		~~>1,25 * t, NOT OK~~		
fi_b	=	beta/6*(3-beta)	=	0,133
gamma	=	(1 - beta) / beta	=	2,376
sigma_c, max	=	M_k / (fi_b*b_t*h_0^2)	=	5,5 MPa
sigma_a, max	=	n * gamma * sigma_c,max	=	85 MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)	=	267 mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5	=	0,07 mm (CRACK WIDTH)
u_0	=	n * sigma_a,max * l^2 / (10 * y_0 * E_ak)	=	3,1 mm (DEFLECTION)
l / u_0	=		=	2.777

LONG TIME — DS 411

fi	=	F_a / b_t /h_0	=	0,0096
n * fi	=		=	0,317
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)	=	0,540
y_0	=	beta * h_0	=	735
		<1,25 * t, OK		
fi_b	=	beta/6*(3-beta)	=	0,221
rho	=	beta*fi_b	=	0,120
I_zt	=	rho*b_t*h_0^3	=	1,81E+11 mm^4
gamma	=	(1 - beta) / beta	=	0,851
sigma_c, max	=	M_d / (fi_b*b_t*h_0^2)	=	5,6 MPa
sigma_a, max	=	n * gamma * sigma_c,max	=	157 MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)	=	267 mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5	=	0,13 mm
u_0	=	n * sigma_c,max * l^2 / (10 * y_0 * E_ak)	=	8,6 mm
l / u_0	=		=	985

Crackwidth acc. to Polish standard

gam_a	=		=	0,00
gam_b	=	(b_t-b_b)*t/(b_b*h_0)	=	0,000
L	=	M_c/(R_bk*b_b*h_0^2)	=	0,10
G	=	gam_b*(1-t/(2*h_0))+gam_a*(1-a/h_0)	=	0,000
my_a	=	F_a/(b_b*h_0)	=	0,010
psi_f	=	1/(1,8+(1+5*(L+G))/(10*n*my_a))	=	0,238
		~~>t/h_0, NOT OK~~ !		
Z_f	=	FORMULA (Z5-9)	=	1199 mm
sigma_a	=	M_c/(Z_f*F__a)	=	261 MPa

n	=	E_ak/E_b	=	6,48
delta_1	=	(b_t-b_b)*t/(b_b*h)	=	0,00
M_fp	=	[0,292+1,5*n/(b_b*h)*(F_a+0,1*F_ac)+0,15*delta_1]*b_b*h^2*R_bzk	=	829 kNm
psi_a	=	1,3-0,8*M_fp/M_c	=	1,000
K_1	=	M_fp/(Z_f*n*F_a*R_bzk) - 2	=	5,85
l_f	=	K_1*n*F_a/(sum u_a)*n_f	=	166 mm
a_sr	=	psi_a*(sigma_a/E_ak)*l_f	=	0,206
k_f	=		=	1,221
a_f	=	k_f*a_sr	=	0,251 mm

<0,3 mm, OK

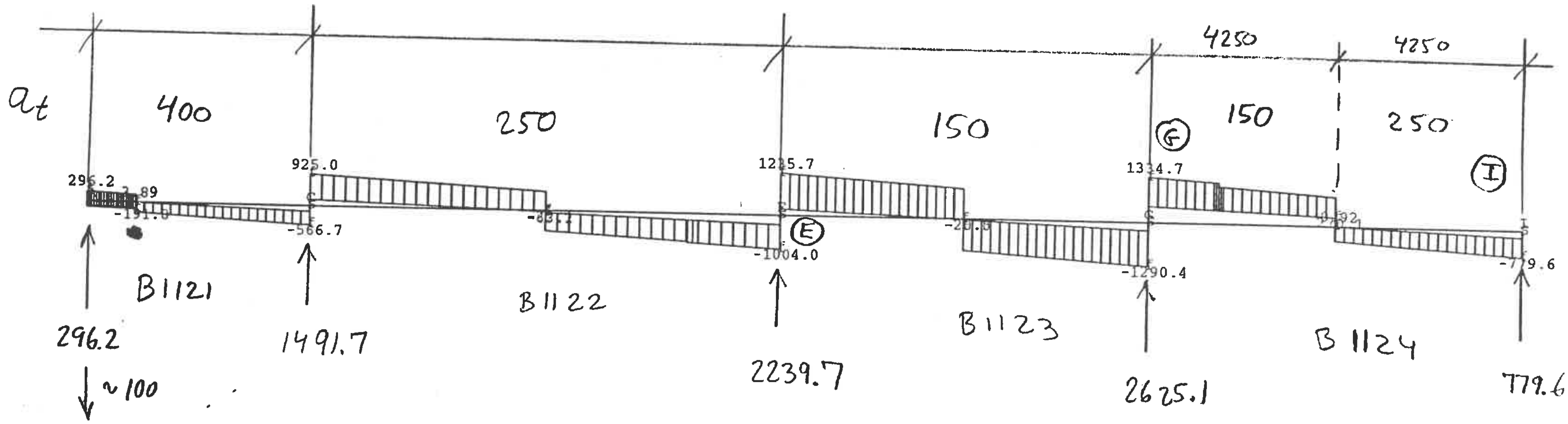
SHEAR REINFORCEMENT Ø12, 4 SECTIONS

ORIENTATION

HORIZONTAL SCALE = 3.2935 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0



4.1-110

SHEAR FORCE ENV. - PRIM. BEAM LEVEL 1, LINE 9-3900

4.1-111

SHEAR CALCULATION acc. to polish standard **SUPPORT G, RIGHT**

STIRRUPS

Bar diameter, d_s			=	12 mm
No. of sections	=		=	4
F_s	=		=	452 mm^2
gam_f0	=		=	1,2
sigma_p	=	(VALUE TAKEN FROM TABLE 12 IN PN-84/B-3264)	=	387 N/mm^2
sigma_ps	=	sigma_p/sqrt(0.1*d_s)	=	353 N/mm^2
sigma_max	=	0,8*R_as**R_b*b_b*h_0/(2.4*gam_f0*Q_1)	=	814 N/mm^2

sigma_ps < sigma_max, OK

Q_1	=		=	1335 kN
Q_min	=	0.75*R_bz*b_b*h_0	=	704 kN
Q_max	=	0,25*R_b*b_b*h_0	=	3491 kN

> Q_1, OK

q	=		=	85 kN/m
SUM_Ni	=		=	0 kN

(SUM_Ni is sum of konc. loads between Q_1 and Q_min)

c_0	=	(Q_1-Q_MIN-SUM_Ni)/q	=	7,420 m

c_0 > h_0 , Q_2,Q_3 ... COULD BE GIVEN !!!

c_01	=	(IF c_0 < h_0 THEN c_01 = c_0)	=	4,25 m
T_1	=	Q_1*c_01/h_0	=	4169 kN
n_s	=	T_1/(gam_f0*sigma_ps*F_s)	=	22
a_t	=	c_01/n_s	=	193 mm
fi_min	=	0,2*R_bzk/0,8*R_ak	=	0,105 %
a_t,min,1	=	F_s/(fi_min*b_b)	=	715 mm
			or	
a_t,min,2	=	0,7*h	=	1015 mm
a_t,min	=	MIN(a_t,min,1 ; a_t,min,2)	=	715 mm

> a_t, OK

4.1 - 112

SHEAR CALCULATION acc. to polish standard SUPPORT I

STIRRUPS

Bar diameter, d_s		=	12 mm
No. of sections	=	=	4
F_s	=	=	452 mm^2
gam_f0	=	=	1,2
sigma_p	= (VALUE TAKEN FROM TABLE 12 IN PN-84/B-3264)	=	387 N/mm^2
sigma_ps	= sigma_p/sqrt(0.1*d_s)	=	353 N/mm^2
sigma_max	= 0,8*R_as**R_b*b_b*h_0/(2.4*gam_f0*Q_1)	=	1392 N/mm^2
		sigma_ps < sigma_max, OK	

Q_1	=	=	780 kN
Q_min	= 0.75*R_bz*b_b*h_0	=	704 kN
Q_max	= 0,25*R_b*b_b*h_0	=	3491 kN
		> Q_1, OK	
q	=	=	85 kN/m
SUM_Ni	=	=	0 kN
	(SUM_Ni is sum of konc. loads between Q_1 and Q_min)		
c_0	= (Q_1-Q_MIN-SUM_Ni)/q	=	0,890 m
		c_0 < h_0 , T_1 = Q_1	
c_01	= (IF c_0 < h_0 THEN c_01 = c_0)	=	0,89 m
T_1	= Q_1*c_01/h_0	=	510 kN
n_s	= T_1/(gam_f0*sigma_ps*F_s)	=	3
a_t	= c_01/n_s	=	297 mm
fi_min	= 0,2*R_bzk/0,8*R_ak	=	0,105 %
a_t,min,1	= F_s/(fi_min*b_b)	=	715 mm
		or	
a_t,min,2	= 0,7*h	=	1015 mm
a_t,min	= MIN(a_t,min,1 ; a_t,min,2)	=	715 mm
		> a_t, OK	

4.1-113

SHEAR CALCULATION acc. to polish standard SUPPORT E, LEFT

STIRRUPS

Bar diameter, d_s			=	12 mm
No. of sections	=		=	4
F_s	=		=	452 mm^2
gam_f0	=		=	1,2
sigma_p	=	(VALUE TAKEN FROM TABLE 12 IN PN-84/B-3264)	=	387 N/mm^2
sigma_ps	=	sigma_p/sqrt(0.1*d_s)	=	353 N/mm^2
sigma_max	=	0,8*R_as**R_b*b_b*h_0/(2.4*gam_f0*Q_1)	=	1082 N/mm^2
		sigma_ps < sigma_max, OK		

Q_1	=		=	1004 kN
Q_min	=	0.75*R_bz*b_b*h_0	=	704 kN
Q_max	=	0,25*R_b*b_b*h_0	=	3491 kN
		> Q_1, OK		
q	=		=	69 kN/m
SUM_Ni	=		=	0 kN
		(SUM_Ni is sum of konc. loads between Q_1 and Q_min)		
c_0	=	(Q_1-Q_MIN-SUM_Ni)/q	=	4,343 m
		c_0 > h_0 , Q_2,Q_3 ... COULD BE GIVEN !!!		
c_01	=	(IF c_0 < h_0 THEN c_01 = c_0)	=	4,343 m
T_1	=	Q_1*c_01/h_0	=	3204 kN
n_s	=	T_1/(gam_f0*sigma_ps*F_s)	=	17
a_t	=	c_01/n_s	=	255 mm
fi_min	=	0,2*R_bzk/0,8*R_ak	=	0,105 %
a_t,min,1	=	F_s/(fi_min*b_b)	=	715 mm
			or	
a_t,min,2	=	0,7*h	=	1015 mm
a_t,min	=	MIN(a_t,min,1 ; a_t,min,2)	=	715 mm
		> a_t, OK		

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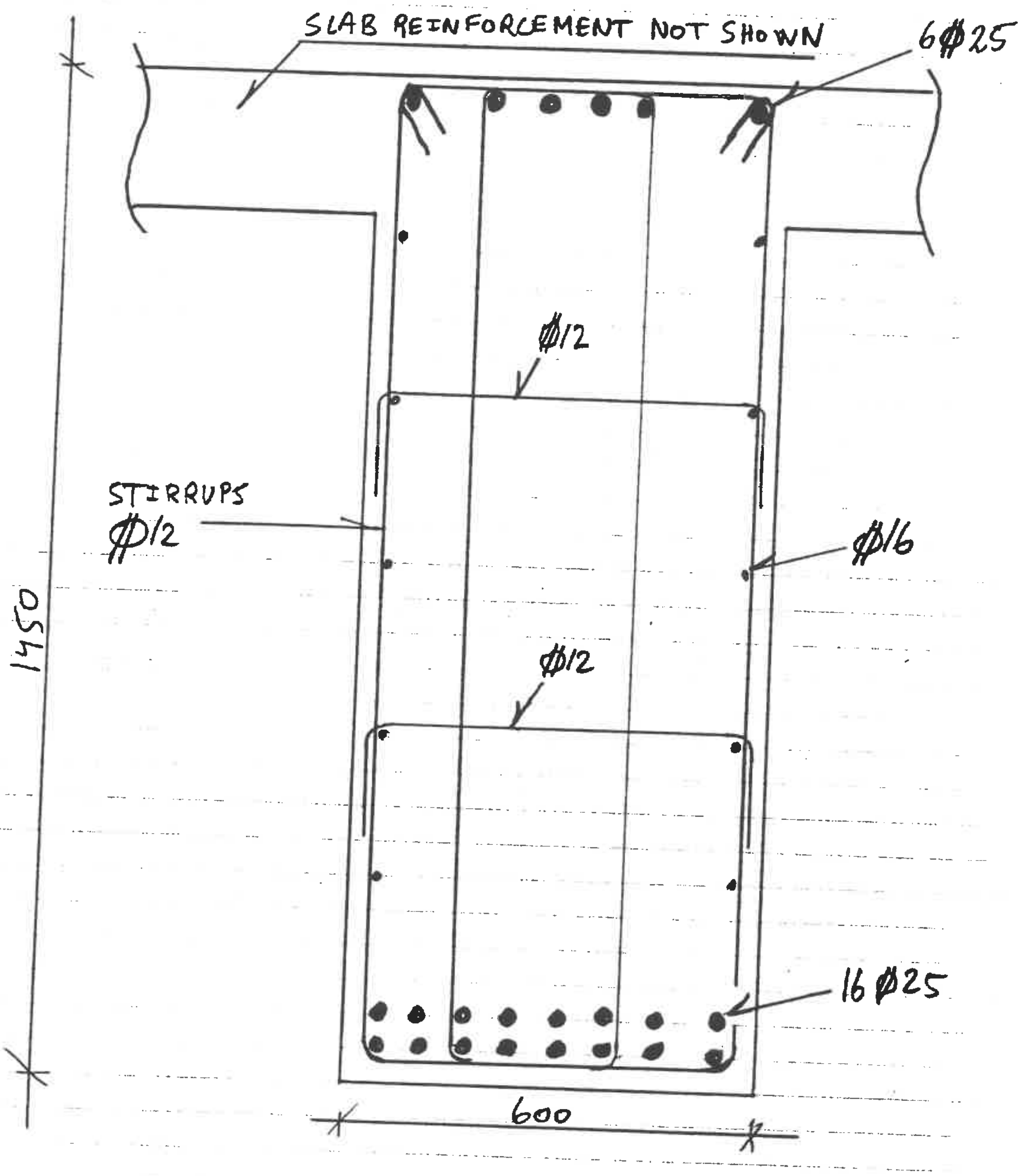
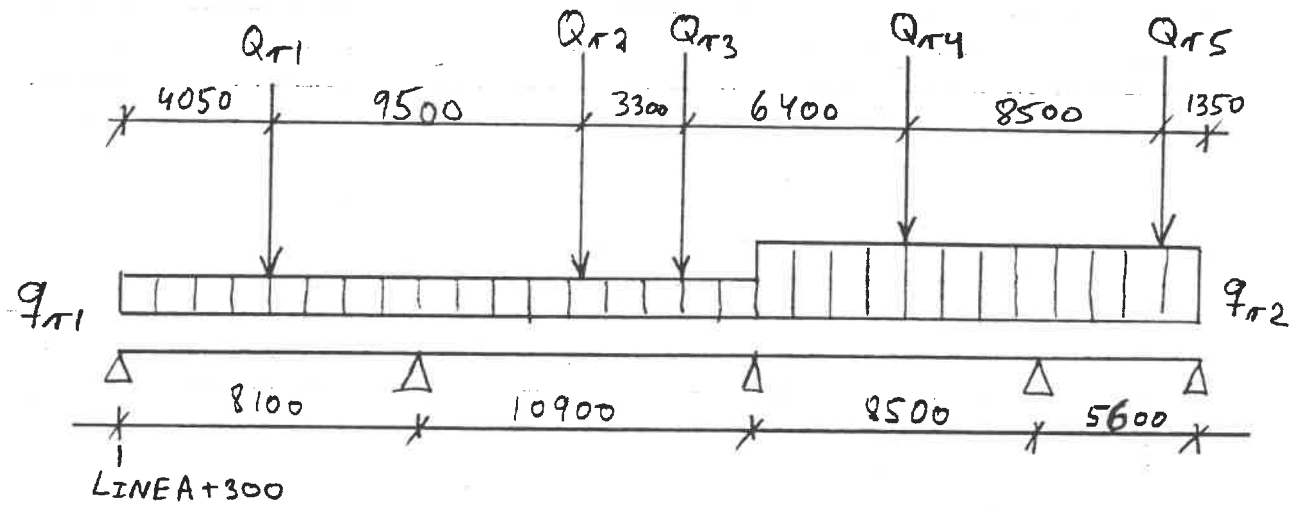
REINFORCEMENT AT MIDSPAN B1124



4.1.6.2 B1131, B1132, B1133, B1134



CROSS SECTION AND q_{r1} / q_{r2} ARE THE SAME AS FOR BEAM B1121, B1122, B1123, B1124.

POINT LOADS:

Q_{r1}: POINT LOAD FROM B1222, B1223

DEAD LOAD $\frac{32}{67} \cdot 653$ = 312 kN

LIVE LOAD $\frac{35}{67} \cdot 653$ = 341 kN

653 kN

Q_{r2}: POINT LOAD FROM B1242, B1243 + CORNER REACTIONS FROM SLABS:

DEAD LOAD $7.8 \cdot 36 - 4 \cdot \frac{5.5}{23} \cdot 45$ = 238 kN

? Q_{v2} = 1221,3   LIVE LOAD $1261 - 7.8 \cdot 36 - 4 \cdot \frac{(10.4+6.5)}{2 \cdot 23} \cdot 45 + 29$ = 943 kN

1181 kN

Q_{r3}: LIVE LOAD = 29 kN

Q_{r4}: POINT LOAD FROM B1262, B1263 + CORNER REACTIONS FROM SLABS:

DEAD LOAD $7.8 \cdot 51 - 4 \cdot \frac{10.63}{120.63} \cdot 167 = 339\ kN$

LIVE LOAD $1982 - 7.8 \cdot 51 - 4 \cdot \frac{13}{120.63} \cdot 167 = 1512\ kN$

$1851\ kN$

Q_{r5}: POINT LOAD FROM B1282:

DEAD LOAD $\frac{51}{97} \cdot 306 = 161\ kN$

LIVE LOAD $\frac{46}{97} \cdot 306 = 145\ kN$

$306\ kN$

q_{r1}:	TOTAL DEAD LOAD	=	40 kN/m
	TOTAL LIVE LOAD	=	29 kN/m
			69 kN/m
q_{r2}:	TOTAL DEAD LOAD	=	50 kN/m
	TOTAL LIVE LOAD	=	35 kN/m
			85 kN/m
Q_{r1}:	TOTAL DEAD LOAD	=	312 kN
	TOTAL LIVE LOAD	=	341 kN
			653 kN
Q_{r2}:	TOTAL DEAD LOAD	=	238 kN
	TOTAL LIVE LOAD	=	943 kN
			1181 kN
Q_{r3}:	TOTAL LIVE LOAD	=	29 kN
Q_{r4}:	TOTAL DEAD LOAD	=	339 kN
	TOTAL LIVE LOAD	=	1512 kN
			1851 kN
Q_{r5}:	TOTAL DEAD LOAD	=	161 kN
	TOTAL LIVE LOAD	=	145 kN
			306 kN

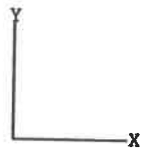
BENDING REINFORCEMENT

TABLE BELOW SHOWS ALLOWABLE MOMENTS IN CROSS SECTION, WITH RESPECT TO ULTIMATE LOAD CAPACITY AND CRACKWIDTH.

NO. Ø25 (TOP/BOTTOM)	MAX. MOMENT [kNm]
16	>2965
14	2300
12	2000
10	1600
8	1200
6	800
4	600
2	300

MOMENT ENVELOPE

ORIENTATION

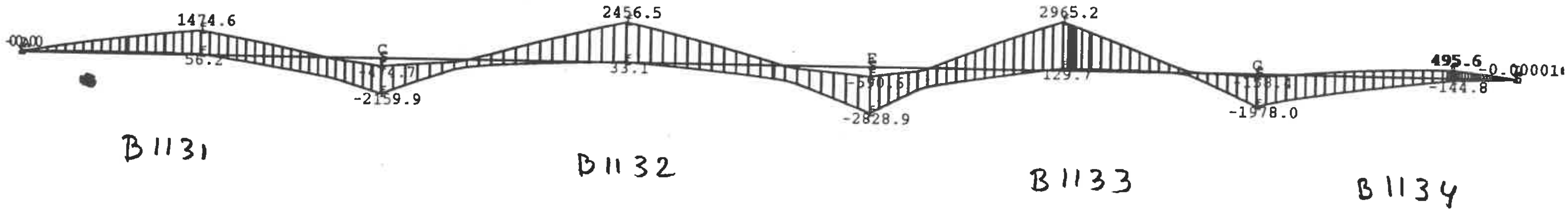


HORIZONTAL SCALE = 3.2935 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0

NOS. OF LOAD COMB. = 15



MOMENT ENV. - PRIM. BEAM LEVEL 1, LINE 9+3900

4.1-119

SHEET A

T-SHAPED BEAM
PRIMARY BEAM
1. LEVEL B1133, AT SUPPORT

GEOMETRY

Height, h	=		=	1.450 mm
Width top., b_t	=		=	600 mm
Width bot., b_b	=		=	600 mm
Flange thick., t	=		=	200 mm
Cover layer, c	=		=	89 mm
Eff. height, h_0	=	h -c	=	1361 mm
Length, l	=		=	8,5 m

REINFORCEMENT

No. of bars	=			=	16 pcs. } TOP
Bar diameter	=			=	25 mm }
F_a	=			=	7854 mm^2
fi (T-beam)	=	F_a / (h * b_f) = F_a / (h * (b_b + 2*t))	>fi_min OK	=	0,54 %
fi (rect. beam)	=	F_a / (h * b_b)	>fi_min OK	=	0,90 %

MATERIALS

R_b	=		=	17,1 MPa
R_bk	=		=	22,2 MPa
R_bzk	=		=	1,7 MPa
R_bz	=		=	1,2 MPa
R_a	=		=	350 MPa
R_ak	=		=	410 MPa
n_short time	=		=	6,48
n_long time	=		=	33,00
E-ak	=		=	210.000 MPa
E_b	=		=	32.400 MPa
fi_min	=	0,45 *R_bzk /R_ak	=	0,19 %

LOADS

M_ult	=		=	2829 kNm
M_k (short time)	=	(50% live load, characteristic load)	=	820 kNm
M_d (long time)	=	(50% live load + 100% dead load, characteristic load)	=	1528 kNm
kap_f	=	1+0,5*(M_k/(M_k+M_d))	=	1,17
M_c	=	M_k+kap_f*M_d	=	2.615 kNm

ULTIMATE LOAD BEARING CAPACITY acc. to ds 411

omega_bal	=			=	0,50
omega	=	(F_a*R_a)/(b_t*h_0*R_b)	< omega_bal OK	=	0,1969
my	=	(1-½*omega)*omega		=	0,1775
beta	=	1,25 * omega		=	0,2461
h_c	=	beta * h_0		=	334,9 mm
M_u,d (+)	=	my * b * h_0^2 * R_b	~~>1,33 * 1 NOT OK~~	=	3.373 kNm
"Safety"	=	M_u,d(+) / M_ult	>M_ult	Load bearing capacity OK =	1,19

ULTIMATE LOAD BEARING CAPACITY acc. to polish standard

X	=	(R_a*F_a)/(b_t*R_b)		=	267,92 mm
psi	=	X/h_0		=	0,20 <psi_gr, OK
psi_gr	=			=	0,50
M_ud	=	R_a*F_a*(h_0 - 0.5*X)		=	3373 KNm
"Safety"	=	M_u,d(+) / M_ult	>M_ult	Load bearing capacity OK =	1,19

4.1 - 120

METHODE B:
ELASTIC ANALYSIS

SHORT TIME		DS 411		
fi	=	F_a / b_t /h_0	=	0,0096
n * fi	=		=	0,062
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)	=	0,296
y_0	=	beta * h_0	=	403 mm
		~~=>1,25 * t, NOT OK~~		
fi_b	=	beta/6*(3-beta)	=	0,133
gamma	=	(1 - beta) / beta	=	2,376
sigma_c, max	=	M_k / (fi_b*b_t*h_0^2)	=	5,5 MPa
sigma_a, max	=	n * gamma * sigma_c,max	=	85 MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)	=	267 mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5	=	0,07 mm
				(CRACK WIDTH)
u_0	=	n * sigma_a,max * l^2 / (10 * y_0 * E_ak)	=	3,1 mm
				(DEFLECTION)
l / u_0	=		=	2.780

LONG TIME		DS 411		
fi	=	F_a / b_t /h_0	=	0,0096
n * fi	=		=	0,317
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)	=	0,540
y_0	=	beta * h_0	=	735
		<1,25 * t, OK		
fi_b	=	beta/6*(3-beta)	=	0,221
rho	=	beta*fi_b	=	0,120
I_zt	=	rho*b_t*h_0^3	=	1,81E+11 mm^4
gamma	=	(1 - beta) / beta	=	0,851
sigma_c, max	=	M_d / (fi_b*b_t*h_0^2)	=	6,2 MPa
sigma_a, max	=	n * gamma * sigma_c,max	=	174 MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)	=	267 mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5	=	0,14 mm
u_0	=	n * sigma_c,max * l^2 / (10 * y_0 * E_ak)	=	9,6 mm
l / u_0	=		=	887

Crackwidth acc. to Polish standard

gam_a	=		=	0,00
gam_b	=	(b_t-b_b)*t/(b_b*h_0)	=	0,000
L	=	M_c/(R_bk*b_b*h_0^2)	=	0,11
G	=	gam_b*(1-t/(2*h_0))+gam_a*(1-a/h_0)	=	0,000
my_a	=	F_a/(b_b*h_0)	=	0,010
psi_f	=	1/(1,8+(1+5*(L+G))/(10*n*my_a))	=	0,235
		~~>t/h_0 ,NOT OK !~~		
Z_f	=	FORMULA (Z5-9)	=	1201 mm
sigma_a	=	M_c/(Z_f*F__a)	=	277 MPa

n	=	E_ak/E_b	=	6,48
delta_1	=	(b_t-b_b)*t/(b_b*h)	=	0,00
M_fp	=	[0,292+1,5*n/(b_b*h)*(F_a+0,1*F_ac)+0,15*delta_1]*b_b*h^2*R_bzk	=	829 kNm
psi_a	=	1,3-0,8*M_fp/M_c	=	1,000
K_1	=	M_fp/(Z_f*n*F_a*R_bzk) - 2	=	5,84
l_f	=	K_1*n*F_a/(sum u_a)*n_f	=	165 mm
a_sr	=	psi_a*(sigma_a/E_ak)*l_f	=	0,218
k_f	=		=	1,158
a_f	=	k_f*a_sr	=	0,253 mm

<0,3 mm, OK

4.1 - 121

SHEET A

T-SHAPED BEAM
PRIMARY BEAM
1. LEVEL B1133, AT MIDSPAN

GEOMETRY

Height, h	=		= 1.450 mm
Width top., b_t	=		= 2.000 mm
Width bot., b_b	=		= 600 mm
Flange thick., t	=		= 200 mm
Cover layer, c	=		= 89 mm
Eff. height, h_0	=	h -c	= 1361 mm
Length, l	=		= 8,5 m

REINFORCEMENT

No. of bars	=			= 16 pcs. } BOTTOM
Bar diameter	=			= 25 mm
F_a	=			= 7854 mm^2
fi (T-beam)	=	F_a / (h * b_f) = F_a / (h * (b_b + 2*t))	>fi_min OK	= 0,54 %
fi (rect. beam)	=	F_a / (h * b_b)	>fi_min OK	= 0,90 %

MATERIALS

R_b	=		= 17,1 MPa
R_bk	=		= 22,2 MPa
R_bzk	=		= 1,7 MPa
R_bz	=		= 1,2 MPa
R_a	=		= 350 MPa
R_ak	=		= 410 MPa
n_short time	=		= 6,48
n_long time	=		= 33,00
E-ak	=		= 210.000 MPa
E_b	=		= 32.400 MPa
fi_min	=	0,45 *R_bzk /R_ak	= 0,19 %

LOADS

M_ult	=		= 2965 kNm
M_k (short time)	=	(50% live load, characteristic load)	= 860 kNm
M_d (long time)	=	(50% live load + 100% dead load, characteristic load)	= 1601 kNm
kap_f	=	1+0,5*(M_k/(M_k+M_d))	= 1,17
M_c	=	M_k+kap_f*M_d	= 2.741 kNm

ULTIMATE LOAD BEARING CAPACITY acc. to ds 411

omega_bal	=			= 0,50
omega	=	(F_a*R_a)/(b_t*h_0*R_b)	< omega_bal OK	= 0,0591
my	=	(1-½*omega)*omega		= 0,0573
beta	=	1,25 * omega		= 0,0738
h_c	=	beta * h_0	<1,33 * t OK	= 100,5 mm
M_u,d (+)	=	my * b * h_0^2 * R_b	>M_ult	= 3.631 kNm Load bearing capacity OK
"Safety"	=	M_u,d(+) / M_ult		= 1,22

ULTIMATE LOAD BEARING CAPACITY acc. to polish standard

X	=	(R_a*F_a)/(b_t*R_b)		= 80,38 mm
psi	=	X/h_0		= 0,06 <psi_gr, OK
psi_gr	=			= 0,50
M_ud	=	R_a*F_a*(h_0 - 0.5*X)	>M_ult	= 3631 KNm Load bearing capacity OK
"Safety"	=	M_u,d(+) / M_ult		= 1,22

METHODE B:
ELASTIC ANALYSIS

4.1-122

SHORT TIME		DS 411			
fi	=	F_a / b_t /h_0	=	0,0029	
n * fi	=		=	0,019	
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)	=	0,176	
y_0	=	beta * h_0	=	239	mm
		<1,25 * t, OK			
fi_b	=	beta/6*(3-beta)	=	0,083	
gamma	=	(1 - beta) / beta	=	4,695	
sigma_c, max	=	M_k / (fi_b*b_t*h_0^2)	=	2,8	MPa
sigma_a, max	=	n * gamma * sigma_c,max	=	85	MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)	=	267	mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5	=	0,07	mm
			(CRACK WIDTH)		
u_0	=	n * sigma_a,max * l^2 / (10 * y_0 * E_ak)	=	2,6	mm
			(DEFLECTION)		
l / u_0	=		=	3.244	

LONG TIME		DS 411			
fi	=	F_a / b_t /h_0	=	0,0029	
n * fi	=		=	0,095	
beta	=	n * fi ((2/(n*fi)+1)^0,5 -1)	=	0,351	
y_0	=	beta * h_0	=	478	
		<1,25 * t, OK			
fi_b	=	beta/6*(3-beta)	=	0,155	
rho	=	beta*fi_b	=	0,055	
I_zt	=	rho*b_t*h_0^3	=	2,75E+11	mm^4
gamma	=	(1 - beta) / beta	=	1,845	
sigma_c, max	=	M_d / (fi_b*b_t*h_0^2)	=	2,8	MPa
sigma_a, max	=	n * gamma * sigma_c,max	=	170	MPa
a_w	=	2 * (h-h_0) * b_b / sigma(d_w)	=	267	mm
w_0	=	0,00005 * sigma_a,max * a_w^0,5	=	0,14	mm
u_0	=	n * sigma_c,max * l^2 / (10 * y_0 * E_ak)	=	6,6	mm
l / u_0	=		=	1.285	

Crackwidth acc. to Polish standard

gam_a	=		=	0,00	
gam_b	=	(b_t-b_b)*t/(b_b*h_0)	=	0,343	
L	=	M_c/(R_bk*b_b*h_0^2)	=	0,11	
G	=	gam_b*(1-t/(2*h_0))+gam_a*(1-a/h_0)	=	0,318	
my_a	=	F_a/(b_b*h_0)	=	0,010	
psi_f	=	1/(1,8+(1+5*(L+G))/(10*n*my_a))	=	0,146	
		< t'/h_0 , OK !			
Z_f	=	FORMULA (Z5-9)	=	1261	mm
sigma_a	=	M_c/(Z_f*F__a)	=	277	MPa

n	=	E_ak/E_b	=	6,48	
delta_1	=	(b_t-b_b)*t/(b_b*h)	=	0,32	
M_fp	=	[0,292+1,5*n/(b_b*h)*(F_a+0,1*F_ac)+0,15*delta_1]*b_b*h^2*R_bzk	=	934	kNm
psi_a	=	1,3-0,8*M_fp/M_c	=	1,000	
K_1	=	M_fp/(Z_f*n*F_a*R_bzk) - 2	=	6,41	
l_f	=	K_1*n*F_a/(sum u_a)*n_f	=	182	mm
a_sr	=	psi_a*(sigma_a/E_ak)*l_f	=	0,240	
k_f	=		=	1,052	
a_f	=	k_f*a_sr	=	0,252	mm

<0,3 mm, OK

CALCULATION OF DEFLECTION

B1132

TRANSFORMED MOMENT OF INERTIA (REF. SPREAD-SHEET)

$I_{zt} = 1.81 \cdot 10^{11}$ mm^4 (AT SUPPORT)

$I_{zt} = 2.75 \cdot 10^{11}$ mm^4 (AT MIDSPAN)

VALUE USED IN GTSTRUDL MODEL:

$I_{zt} = 2.28 \; 10^{11}$ mm^4

LONG ACTING LOAD : (DEAD LOAD + 50% LIVE LOAD)

$$\sim \frac{1}{1.2} \frac{40 + 0.5 \cdot 29 + 2 \cdot 238/10.9 + 0.5 \cdot 2 \cdot 943/10.9}{40 + 29 + 2 \cdot 1181/10.9} \cdot 100\% = 54\%$$

OF TOTAL DESIGN LOAD

$E = 6400 \; N/mm^2$

SHORT ACTING LOAD : (50% LIVE LOAD)

$$\sim \frac{1}{1.2} \cdot \frac{0.5 \cdot 29 + 0.5 \cdot 2 \cdot 943/10.9}{40 + 29 + 2 \cdot 1181/10.9} \cdot 100\% = 29\%$$

OF TOTAL DESIGN LOAD.

MAX. DISPLACEMENT FROM LONG ACTING LOAD :

$0.54 \cdot 7.5 = \underline{\underline{4.1 \; mm}}$

THIS VALUE IS CALCULATED WITH THE USE OF GT STRUDL.

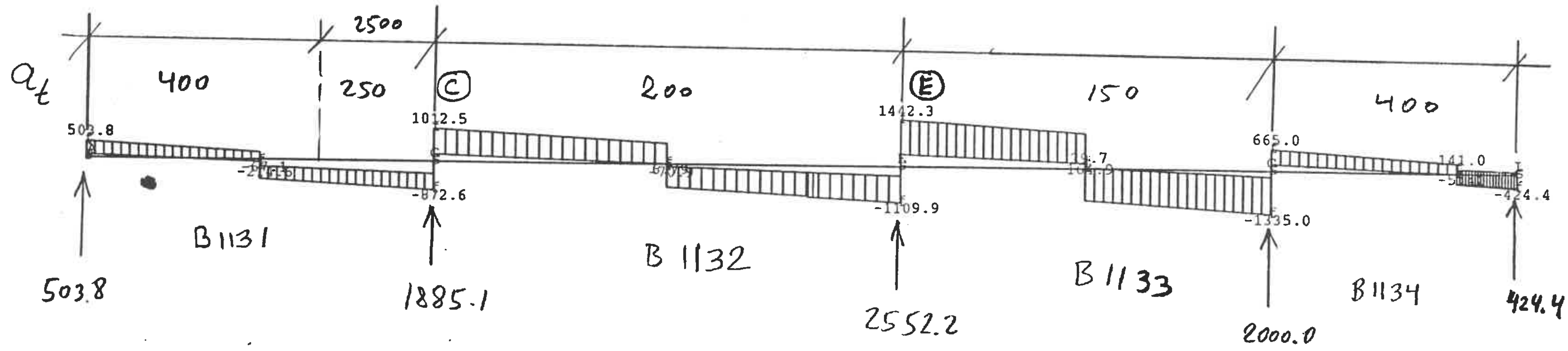
SHEAR REINFORCEMENT Ø12, 4 SECTIONS

ORIENTATION

HORIZONTAL SCALE = 3.2935 UNITS PER INCH

VERTICAL SCALE = 5.6338 UNITS PER INCH

EQUIVALENT ROTATION Z .0 Y .0 X .0



SHEAR FORCE ENV. - PRIM. BEAM LEVEL 1. LINE 9:3900

4.1-12Y

4.1-125

SHEAR CALCULATION acc. to polish standard SUPPORT E, LEFT

STIRRUPS				
Bar diameter, d_s			=	12 mm
No. of sections	=		=	4
F_s	=		=	452 mm^2
gam_f0	=		=	1,2
sigma_p	=	(VALUE TAKEN FROM TABLE 12 IN PN-84/B-3264)	=	387 N/mm^2
sigma_ps	=	sigma_p/sqrt(0.1*d_s)	=	353 N/mm^2
sigma_max	=	0,8*R_as**R_b*b_b*h_0/(2.4*gam_f0*Q_1)	=	978 N/mm^2
		sigma_ps < sigma_max, OK		

Q_1	=		=	1110 kN
Q_min	=	0.75*R_bz*b_b*h_0	=	704 kN
Q_max	=	0,25*R_b*b_b*h_0	=	3491 kN
		> Q_1, OK		
q	=		=	69 kN/m
SUM_Ni	=		=	0 kN
	(SUM_Ni is sum of konc. loads between Q_1 and Q_min)			
c_0	=	(Q_1-Q_MIN-SUM_Ni)/q	=	5,879 m
		c_0 > h_0 , Q_2,Q_3 ... COULD BE GIVEN !!!		
c_01	=	(IF c_0 < h_0 THEN c_01 = c_0)	=	5,45 m
T_1	=	Q_1*c_01/h_0	=	4445 kN
n_s	=	T_1/(gam_f0*sigma_ps*F_s)	=	24
a_t	=	c_01/n_s	=	227 mm
fi_min	=	0,2*R_bzk/0,8*R_ak	=	0,105 %
a_t,min,1	=	F_s/(fi_min*b_b)	=	715 mm
				or
a_t,min,2	=	0,7*h	=	1015 mm
a_t,min	=	MIN(a_t,min,1 ; a_t,min,2)	=	715 mm
		> a_t, OK		

4.1-126

SHEAR CALCULATION acc. to polish standard SUPPORT E, RIGHT

STIRRUPS				
Bar diameter, d_s			=	12 mm
No. of sections	=		=	4
F_s	=		=	452 mm^2
gam_f0	=		=	1,2
sigma_p	=	(VALUE TAKEN FROM TABLE 12 IN PN-84/B-3264)	=	387 N/mm^2
sigma_ps	=	sigma_p/sqrt(0.1*d_s)	=	353 N/mm^2
sigma_max	=	0,8*R_as**R_b*b_b*h_0/(2.4*gam_f0*Q_1)	=	753 N/mm^2
		sigma_ps < sigma_max, OK		

Q_1	=		=	1442 kN
Q_min	=	0.75*R_bz*b_b*h_0	=	704 kN
Q_max	=	0,25*R_b*b_b*h_0	=	3491 kN
		> Q_1, OK		
q	=		=	85 kN/m
SUM_Ni	=		=	0 kN
	(SUM_Ni is sum of konc. loads between Q_1 and Q_min)			
c_0	=	(Q_1-Q_MIN-SUM_Ni)/q	=	8,679 m
		c_0 > h_0 , Q_2,Q_3 ... COULD BE GIVEN !!!		
c_01	=	(IF c_0 < h_0 THEN c_01 = c_0)	=	4,25 m
T_1	=	Q_1*c_01/h_0	=	4503 kN
n_s	=	T_1/(gam_f0*sigma_ps*F_s)	=	24
a_t	=	c_01/n_s	=	177 mm
fi_min	=	0,2*R_bzk/0,8*R_ak	=	0,105 %
a_t,min,1	=	F_s/(fi_min*b_b)	=	715 mm
			or	
a_t,min,2	=	0,7*h	=	1015 mm
a_t,min	=	MIN(a_t,min,1 ; a_t,min,2)	=	715 mm
		> a_t, OK		

4.1-127

SHEAR CALCULATION acc. to polish standard SUPPORT C, LEFT

STIRRUPS				
Bar diameter, d_s			=	12 mm
No. of sections	=		=	4
F_s	=		=	452 mm^2
gam_f0	=		=	1,2
sigma_p	=	(VALUE TAKEN FROM TABLE 12 IN PN-84/B-3264)	=	387 N/mm^2
sigma_ps	=	sigma_p/sqrt(0.1*d_s)	=	353 N/mm^2
sigma_max	=	0,8*R_as**R_b*b_b*h_0/(2.4*gam_f0*Q_1)	=	1244 N/mm^2
		sigma_ps < sigma_max, OK		

Q_1	=		=	873 kN
Q_min	=	0.75*R_bz*b_b*h_0	=	704 kN
Q_max	=	0,25*R_b*b_b*h_0	=	3491 kN
		> Q_1, OK		
q	=		=	69 kN/m
SUM_Ni	=		=	0 kN
	(SUM_Ni is sum of konc. loads between Q_1 and Q_min)			
c_0	=	(Q_1-Q_MIN-SUM_Ni)/q	=	2,445 m
		c_0 > h_0 , Q_2,Q_3 ... COULD BE GIVEN !!!		
c_01	=	(IF c_0 < h_0 THEN c_01 = c_0)	=	2,445 m
T_1	=	Q_1*c_01/h_0	=	1568 kN
n_s	=	T_1/(gam_f0*sigma_ps*F_s)	=	9
a_t	=	c_01/n_s	=	272 mm
fi_min	=	0,2*R_bzk/0,8*R_ak	=	0,105 %
a_t,min,1	=	F_s/(fi_min*b_b)	=	715 mm
			or	
a_t,min,2	=	0,7*h	=	1015 mm
a_t,min	=	MIN(a_t,min,1 ; a_t,min,2)	=	715 mm
		> a_t, OK		