Blast Proof Occupied Buildings

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Contents Presentation

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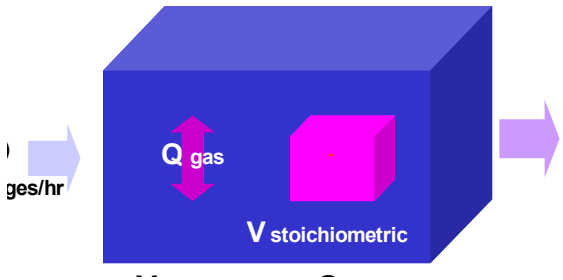
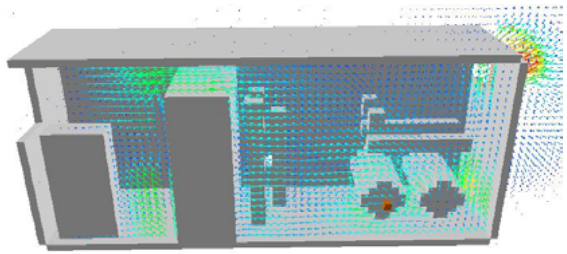
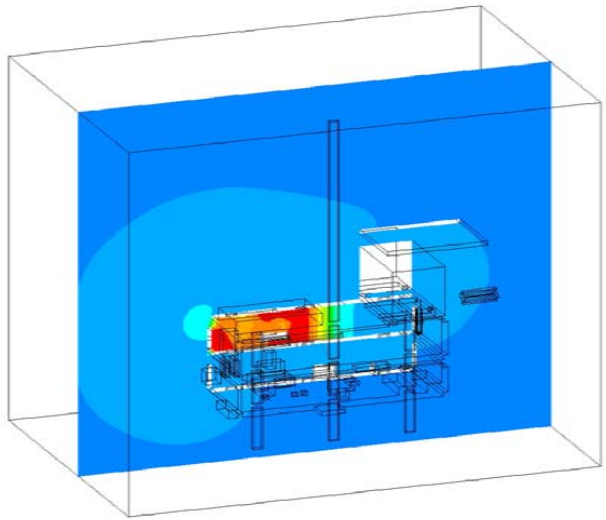
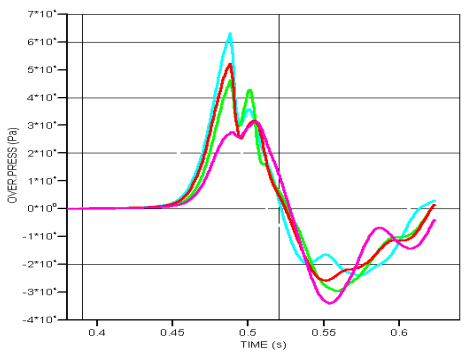
- Functional Specification Blast Resistant Building
- Basis for design
- Blast & impact loading
- Design modeling & analyses
- Preliminary design
- Design details

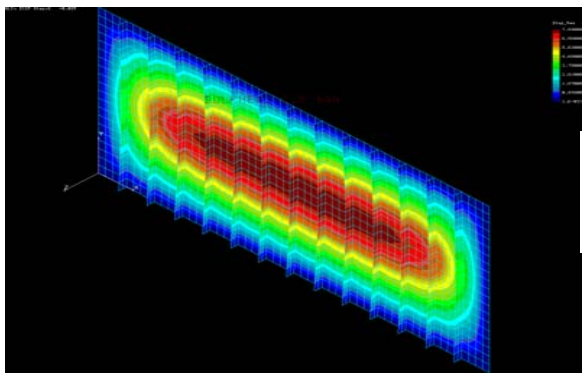
Explosion Analyses & Blast Resistant Design











wintershall
BASF Group

NAM

bp

hertel

ustoMSC

BASF
The Chemical Company

VANDENBORRE
HYDROGEN SYSTEMS

Chevron

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References Blast Resistant Onshore Modular Buildings

BASF Seal Sands Workshop

Blast resistance check 0,9 Psi

Shell Pernis for Hertel CKT

Blast Resistant Modular Building 8 Psi

BP Refineries for Hertel

Blast Resistant Modular Building 13 Psi

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ATEX 137 Implementation & Training

NAM

Glaverbel

sabic

DSM

NLON

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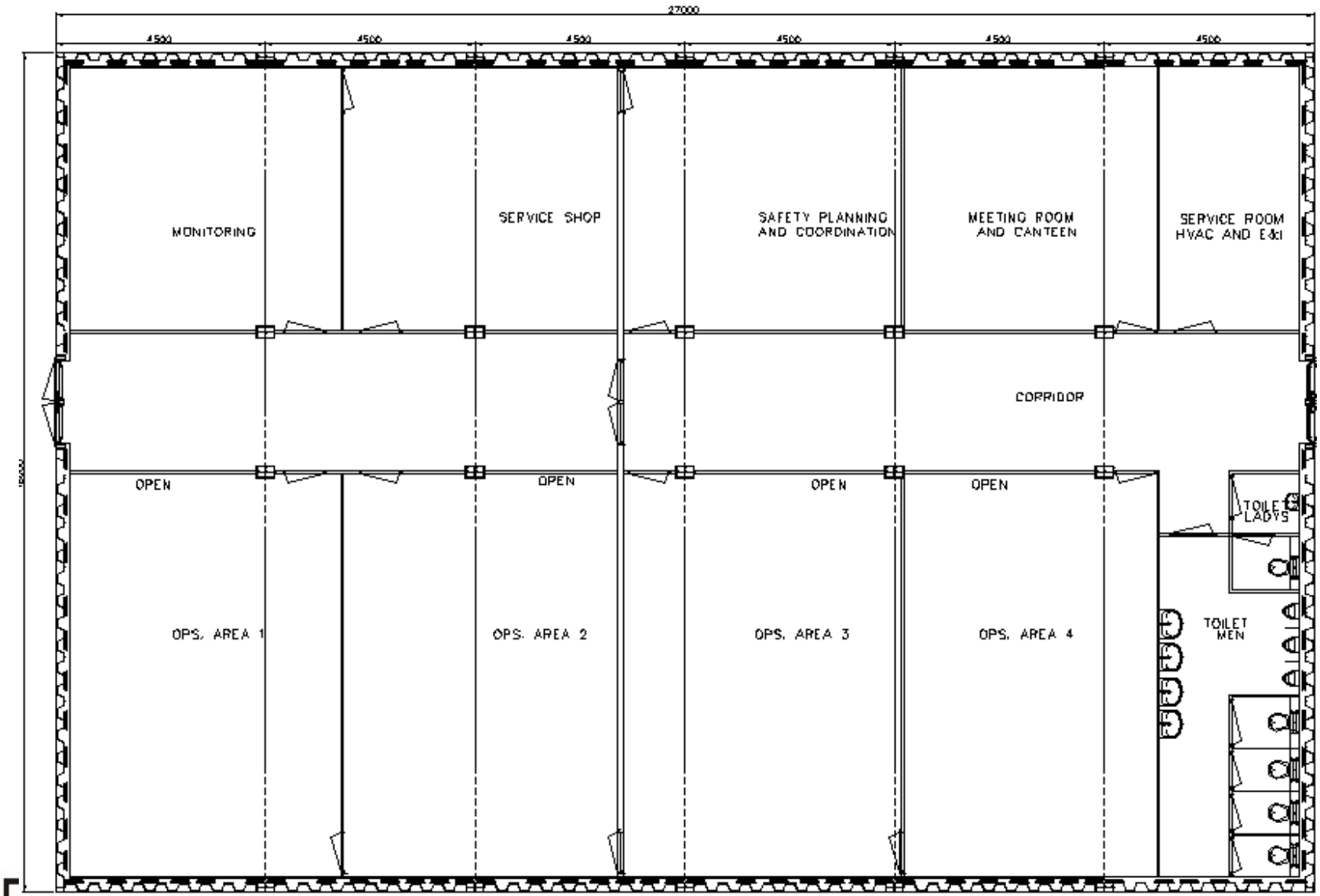
- **Frame work structural steel; external walls corrugated plating**
- **Blast overpressure resistance: 970 mbar; 92,3 millisecond**
- **Explosion driven 6 inch, 300 lbs blind flange impact resistance**

Blast resistant building lay out Shell Pernis



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Basis for design specifications;codes & standards

- **Specifications:**
  - GP 04-30

    Guidance on practice for design and location of occupied permanent buildings subject to blast, fire and gas hazards on onshore facilities
  - GP 04-20

    Guidance on Practice for Civil Engineering
  - DEP 34.17.10.30-Gen (optional)

    Technical specification blast resilient and blast resistant control buildings/field auxiliary rooms

- **Codes and Standards**
  - ARMY TM 5-1300

    Structures to resist the effect of accidental explosions
  - PGS 1, part 2B: Effects of explosions on constructions; VROM/SZW;

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Basis for design material properties

- ***Material strength***

  Applied yield strength Fy = 355 N/mm² (St. 52 or equivalent)

  Ultimate strength Fu = 510 N/mm²

- ***Dynamic yield stress***

  Fdy = Fy x SIF x DIF

  SIF = Strength increase factor

  SIF = 1,1 for structural steel

  SIF = 1,2 for cold formed steel cladding panels

  DIF = Dynamic increase factor:

  DIF = 1.29 for bending/ shear

  DIF = 1.19 for tension/ compression

- ***Applied material properties***

  Structural steel Fdy = 504/465 N/mm² (Bending-Shear/tension-compression)

  Sheeting Fdy = 550/507 N/mm²(Bending-Shear/tension-compression)

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Basis for design criteria

Deformation limits

Element	Ductility	Rotation	Deflection
	μ	Θ º	
Beams/girths	20	12	
Frame members	3	3	δ < H/25 mm
Metal sheet panels	6	4	
Open web joints	2	2	
Plates	1.5	12	

Ductility μ *=Total (plastic) deformation/elastic deformation*
H = Frame height in mm

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Load combinations

- **Overall strength analysis blast resistant building**
  - Dead weight + frame blast loading
    - Longitudinal direction
    - Transverse direction
- **Local strength analysis wall and roof panels**
    - Reflected over pressure
    - Impact loading walls
- **Floor**
  - Dead weight + live load (3kN/m²
- **Stability**
  - Dead weight + frame blast loading

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Design modeling & analyses

- **Computer programs & analyses**

  - ***Local wall and roof analyses***

    The structural impact and response to the blast pressures to the external walls and roof are analysed by means of a time domain non-linear physical excel software.

  - ***Overall frame design***

    The overall structural blast response calculation is performed with the software STAAD.PRO.

    The peak dynamic reactions from the walls and roof are applied to the frame members.

Design model & analysis outside wall panels

TITLE :	BPB BP Rotterdam Corrugated sheeting outside walls
CLIENT :	Hertel
PROJECT :	
DOC NR:	
FILE NR:	

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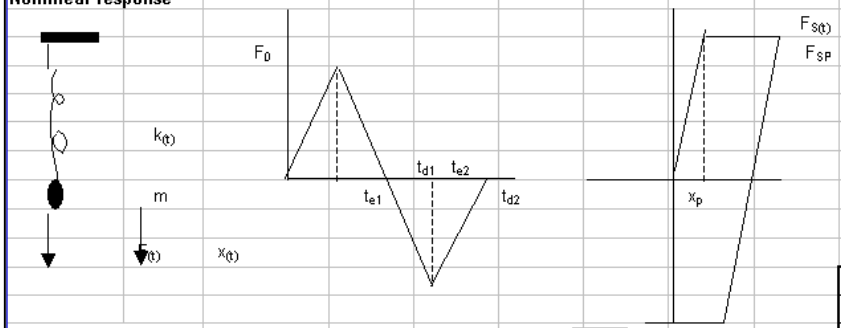
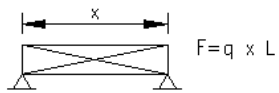
REV.	DATE	ORIG.	CHK'D	KCI APPR.	CLIENT APPR.
1	24/04/2008	D.S			
2					
3					

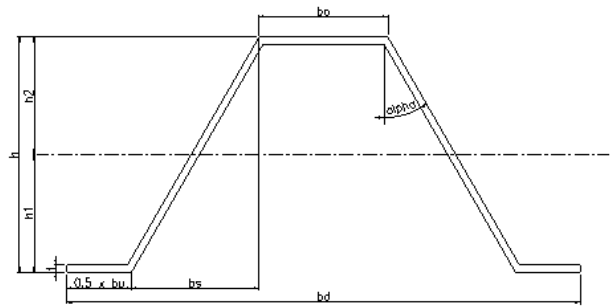
Nonlinear response





BRM outside wall
Corrugated sheeting 640/160-8
Steel 355

Corrugated sheet



Beam dimensions

b_u	240	[mm]
b_s	80	[mm]
b_o	240	[mm]
α	26.7	[deg]
h	160	[mm]
b_d	640	[mm]
t	8	[mm]
E	210000	N/mm²
σ_{yield}	550	N/mm²

Beam properties

$height_1$	80.0	mm
$height_2$	80.0	mm
z	80.0	mm
Ixx	27421121	mm^4
Ze	342764	mm^3
Z_p	421822	mm^3
A	6706	mm2
L	3390	[mm]

Input data

k	22703699	N/m
k	22703699	[N/m]
m	178.44	[kg]
Z_p	4.2E-04	[m^3]
σ_{yield}	550000000	[N/m^2]
L	3.39	[m]
KLMe	0.78	
KLMp	0.66	

calculated

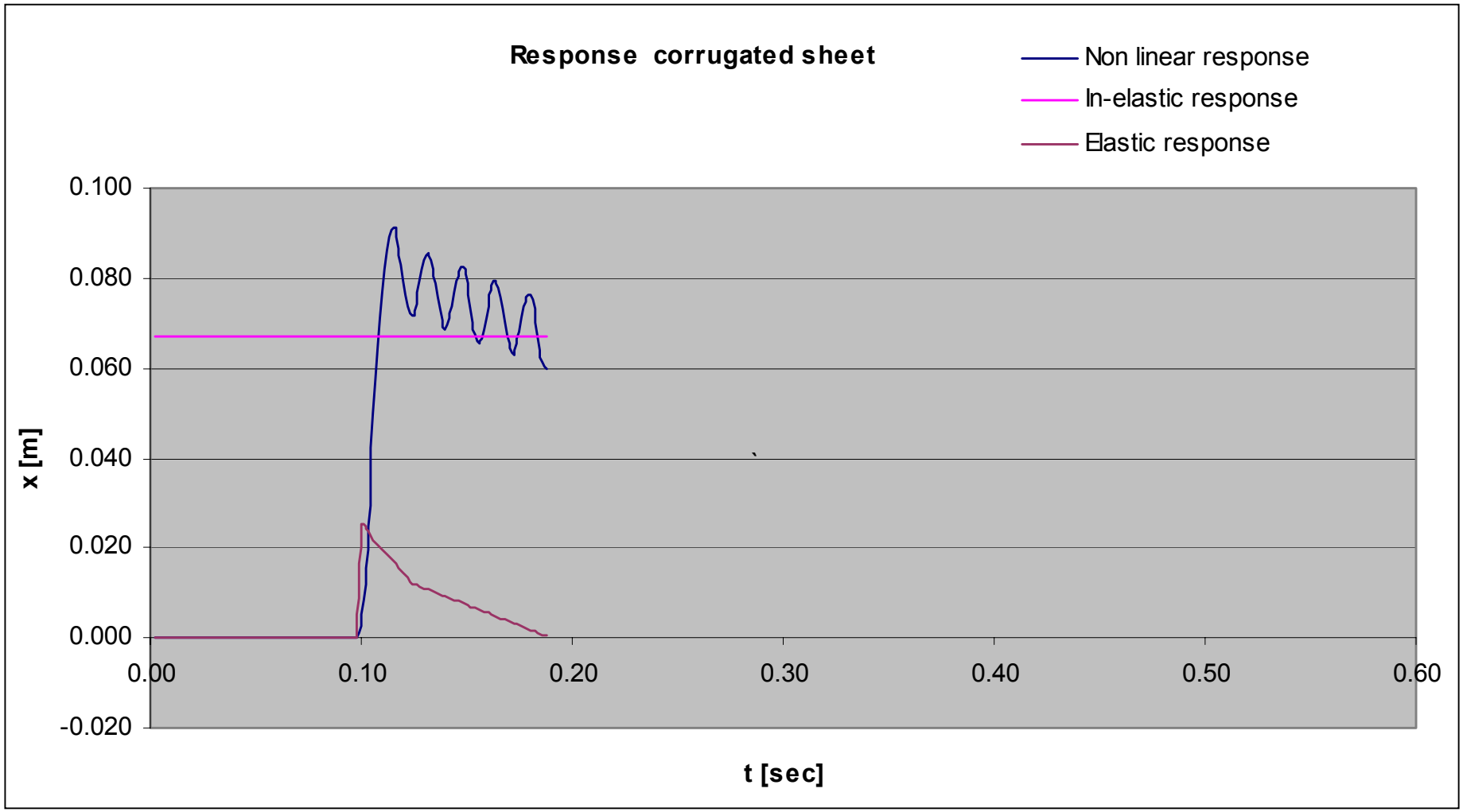
M_p	232002.09	[Nm]
F_{smax}	547497.56	[N]
x_p	0.024	[m]
T	0.0199451	[sec]
t1/T	-	
Me el	139.18689	
Me pl	117.77352	

Maximum support reaction		
Maximum	270623	[N]
Minimum	-61132	[N]

DAF =	0.95

Ductility ratio μ = Total deformation/elastic deformation	= 3.8	<	Allowable = 6
Support rotation θ = arctang (total deformation/L/2)	= 3.1 °		Allowable = 4 °

Design model & analysis outside wall panels



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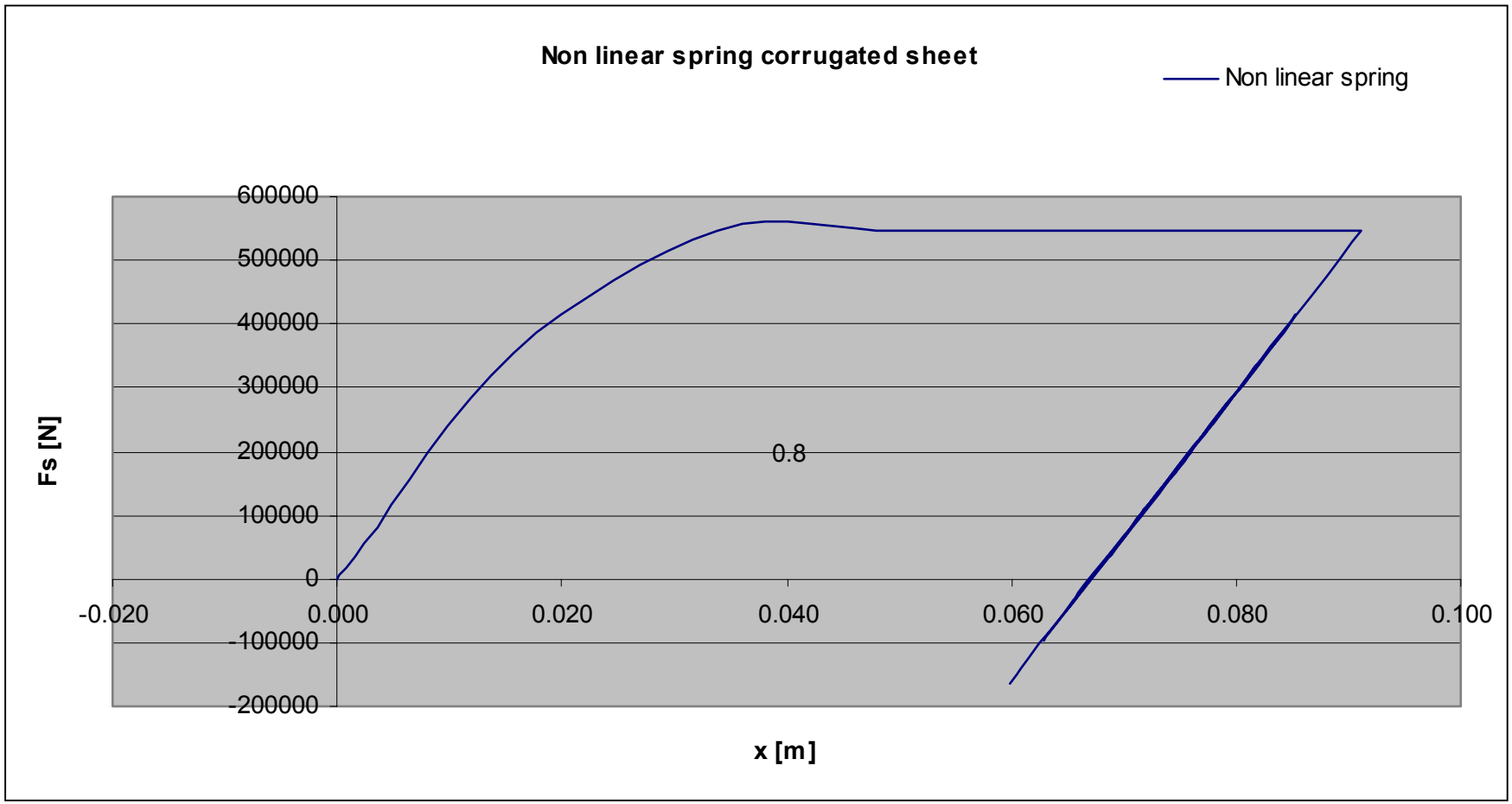
Design model & analysis outside wall panels



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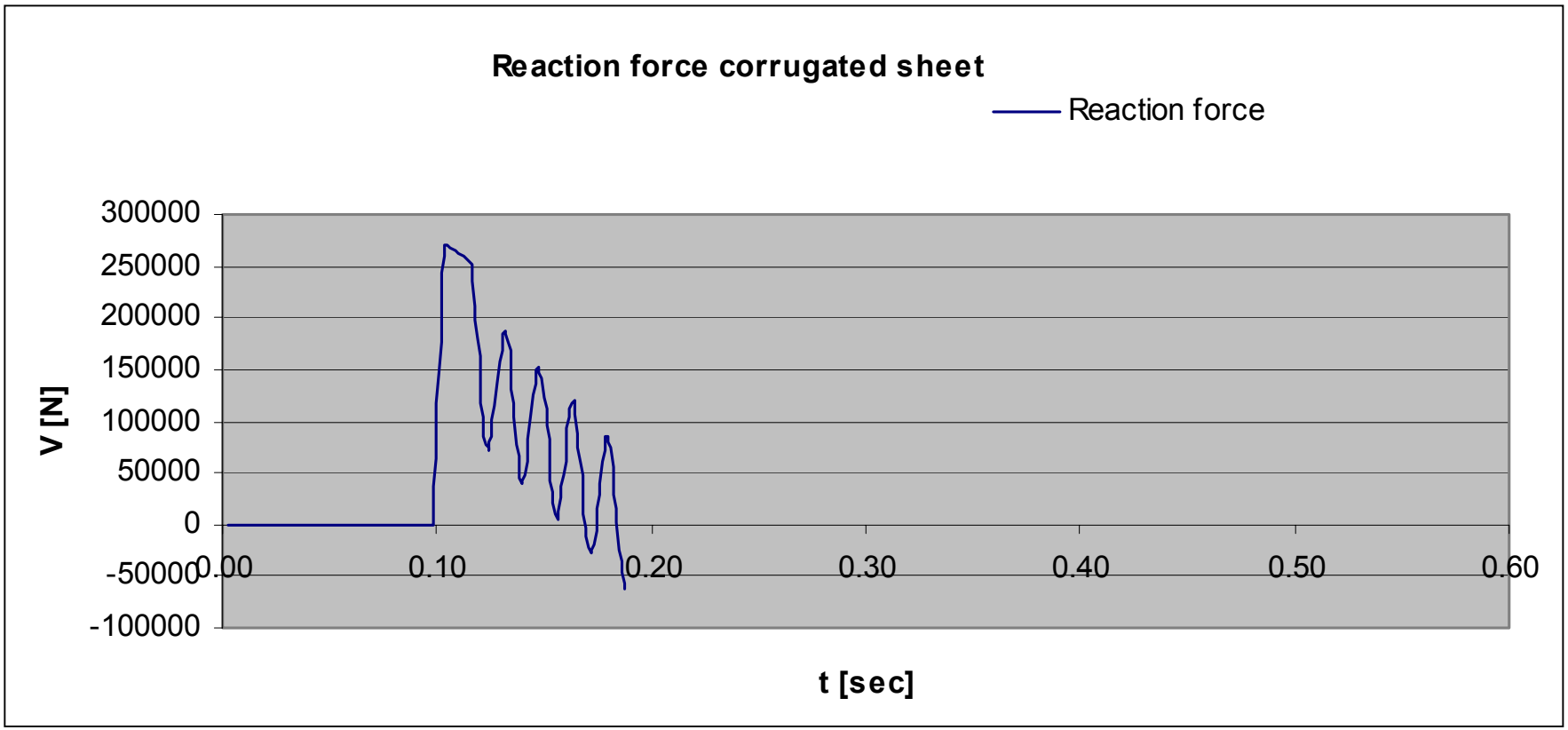
Design model & analysis outside wall panels



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Design model and analysis roof panels

TITLE : BRB BP Rotterdam roof/side walls transvere loading		REV.	DATE	ORIG.	CHK'D	KCI APPR.	CLIENT APPR.
CLIENT : CKT Hertel		1	4/24/2008	DS			
PROJEC 8022		2					
DOC NR		3					
FILE NR:							

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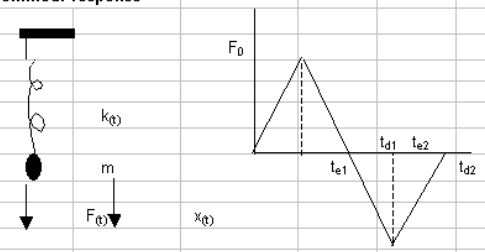
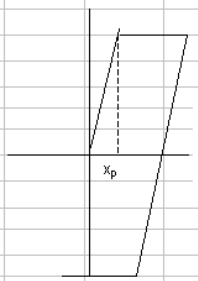
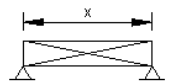
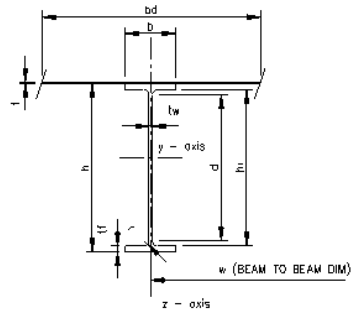
Nonlinear response







BRB roof
IPE 160 h.o.h. 375 mm.
Plating 5 mm.
Steel 355



Input data		
k	2739641	N/m
k	2739641	[N/m]
m	124.90	[kg]
Z_p	7.E-05	[m^3]
σ_{yield}	504000000	[N/m^2]
L	4.4	[m]
KLMe	0.78	
KLMp	0.66	

calculated		
M_p	3.5E+04	[Nm]
F_{smax}	6.3E+04	[N]
x_p	0.023	[m]
T	0.048035633	[sec]
Me el	97.4204546	
Me pl	82.43269236	

Beam dimensions / properties		
h	160	[mm]
b	82	[mm]
t_w	5	[mm]
t_f	7.4	[mm]
r	9	[mm]
A	1939.6	[mm^2]
h_i	145.2	[mm]
d	127	[mm]
I_y	8692922.28	[mm^4]
$W_{el.y}$	108662	[mm^3]
$W_{pl.y}$	123953	[mm^3]
i_y	66.9	[mm]
A_{vz}	21250	[mm^2]
b_d	335	[mm]
L	4400	[mm]
E	210000	N/mm^2
σ_{yield}	504	N/mm^2

Plate dimensions / properties		
t	5	[mm]
w	375	[mm]
b_d	335	[mm]
A_{plate}	1676	[mm^2]
$I_{x\ plate}$	3286364	[mm^4]
$W_{el.y}$	1314545	[mm^3]
$W_{pl.y}$	74186	[mm^3]
σ_{yield}	504	N/mm^2

z_{elas}	47	[mm]
z_{plas}	-82.6	[mm]
A_{tot}	3616	[mm^2]
Iy_{tot}	14470087.69	[mm^4]
Iz_{tot}	16386706	[mm^4]
$W_{el\_y\_tot}$	122371	[mm^3]
$W_{el\_z\_tot}$	97747	[mm^3]
$T_{el\_x\_tot}$	5138218.258	[mm^4]
Z_p	68727.05586	[mm^3]

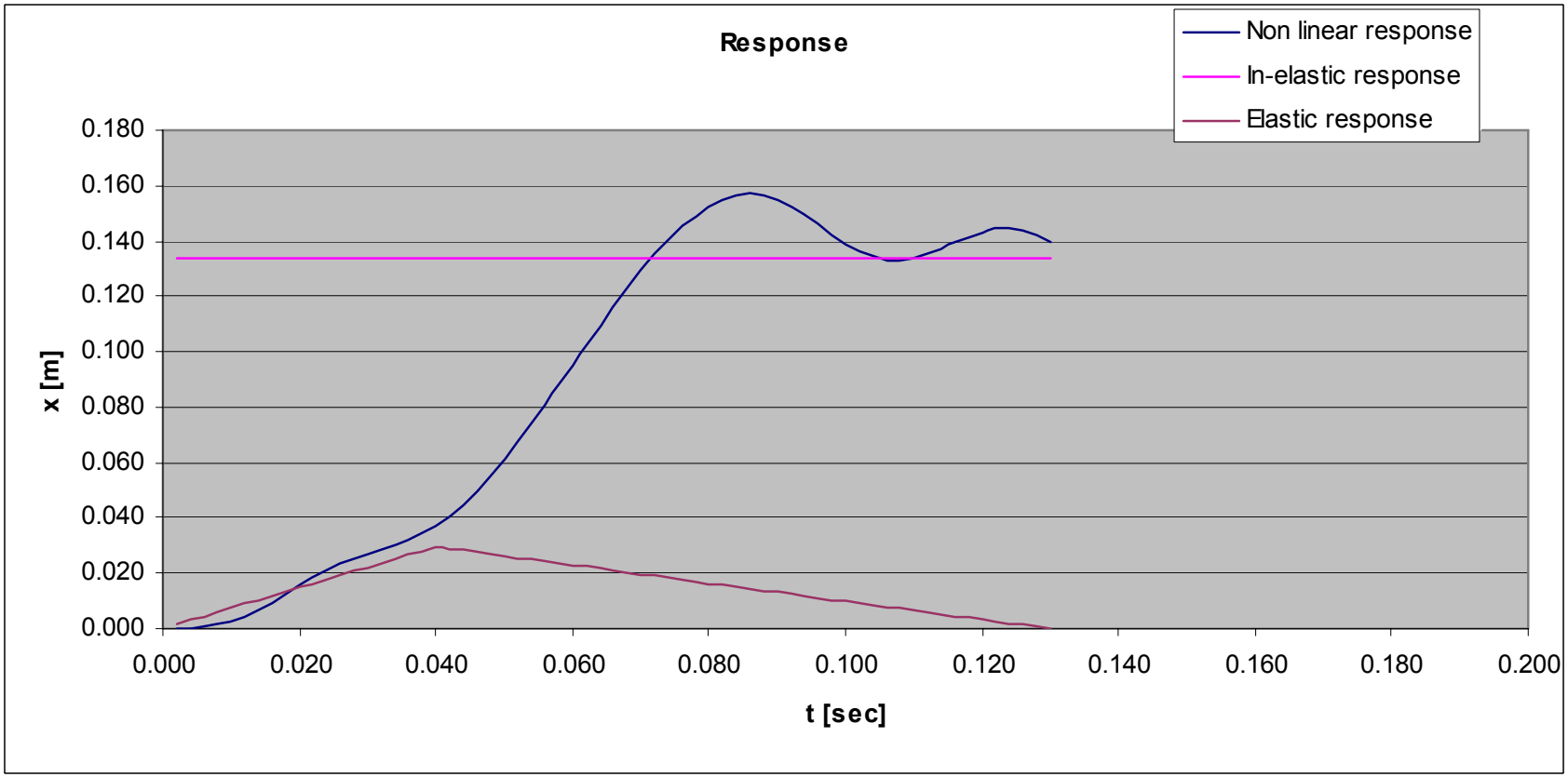
bd = c x w	335	mm
c = 0.1 + 0.9 log Lo/w =		0.9
Lo = 0.65 L	2860	mm
Lo/w	7.6	
log Lo/w	0.9	
0.9log Lo/w	0.8	
A_1	1676	
A_2	607	
A_3	726	
A_4	606.8	
shear z	726	
shear y	2890	

DAF = 1.04

Support reaction		
Maximum	33634	[N]
Minimum	485	[N]

Ductility ratio μ = Total deformation/elastic deformation = 5.2 < Allowable = 20
Support rotation θ = arctang (total = deformation/2L) = 4.1 ° < Allowable = 12 °

Design model and analysis roof panels



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Design model and analysis floor

TITLE :	BRB BP Rotterdam Floor
CLIENT :	Hertel
PROJECT :	8022
DOC NR:	
FILE NR:	

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REV.	DATE	ORIG.	CHK'D	KCI APPR.	CLIENT APPR.
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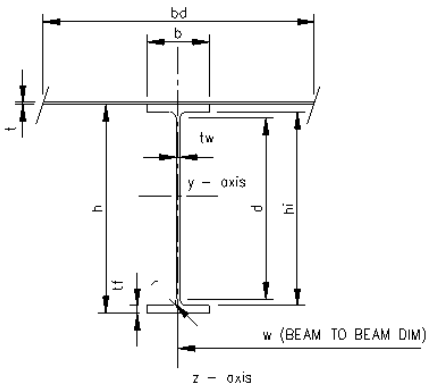
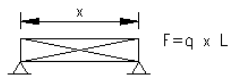
3					





BRM floor
IPE 120 h.o.h. 600 mm.
Plating 5 mm.
Steel 355

Loading		
q	3000	N/m²

bd = c x w	426	mm	
c = 0.1 + 0.9 log Lo/w =		0.7	
Lo = 0.65 L	2860	mm	
Lo/w	4.8		
log Lo/w	0.7		
0.9log Lo/w	0.6		
M	4356	Nm	
σ	70	N/mm²	
f	6.8	mm	
σall =	0.6 σyield	213	N/mm²
fall =	L/600	7.3	mm

UC = σ/σyield	0.3
L/f =	651

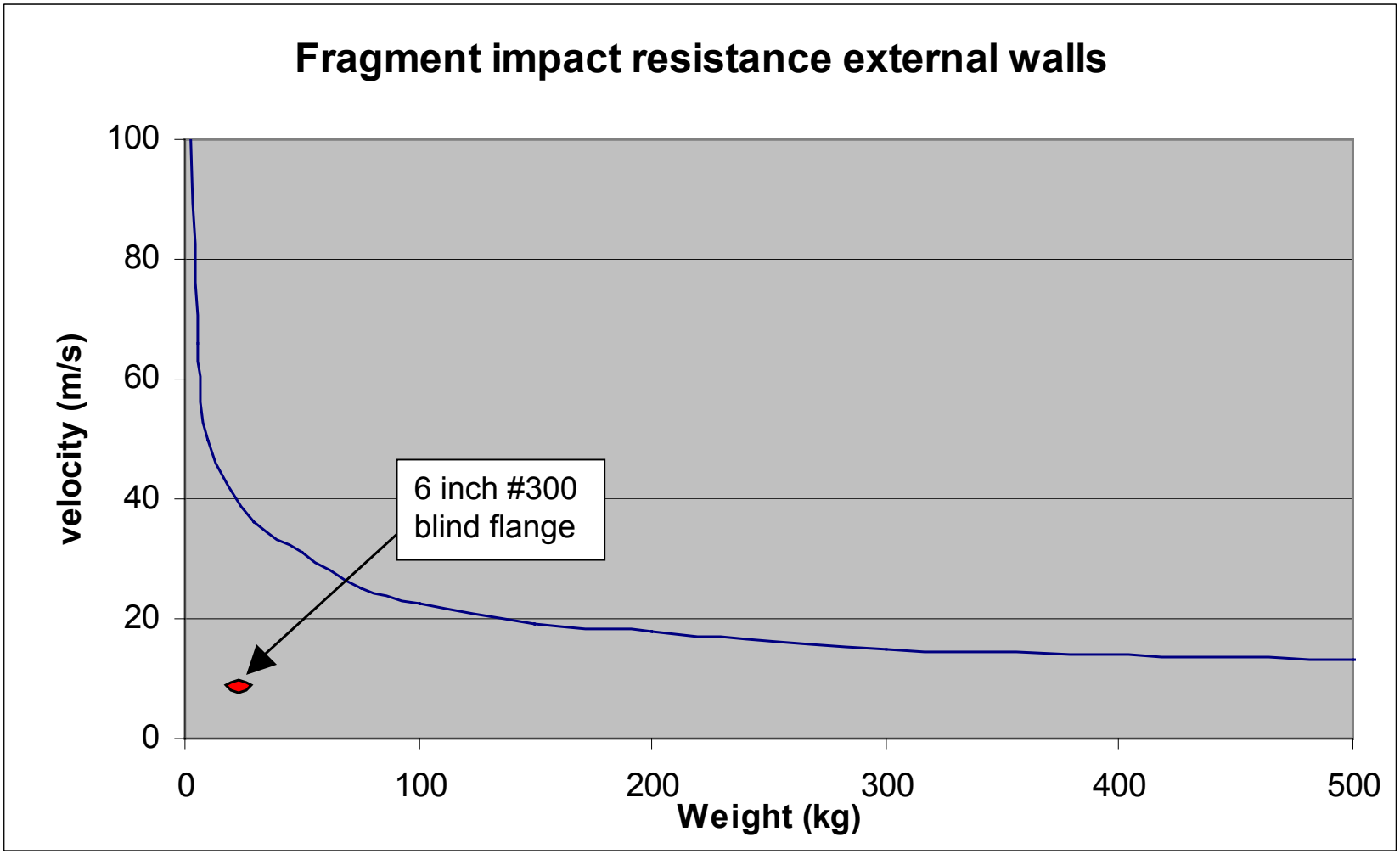
Beam dimensions / properties

h	120	[mm]
b	64	[mm]
t_w	4.4	[mm]
t_f	6.3	[mm]
r	7	[mm]
A	1279	[mm²]
h_i	107.4	[mm]
d	93	[mm]
I_y	3177531.492	[mm⁴]
$W_{el,y}$	52959	[mm³]
i_y	49.8	[mm]
A_{vz}	21250	[mm²]
b_d	426	[mm]
L	4400	[mm]
E	210000	N/mm²
σ_{yield}	355	N/mm²

Plate dimensions / properties

t	5	[mm]
w	600	[mm]
b_d	426	[mm]
A_{plate}	2131	[mm²]
$I_{x\ plate}$	1175420	[mm⁴]
$W_{el,y}$	470168	[mm³]
σ_{yield}	355	N/mm²
z_{elas}	26	[mm]
A_{tot}	3410	[mm²]
Iy_{tot}	6189798	[mm⁴]
Iz_{tot}	32541565	[mm⁴]
$W_{el\_y\_tot}$	62486	[mm³]
$W_{el\_z\_tot}$	152693	[mm³]
$T_{el\_x\_tot}$	1845384	[mm⁴]

Fragment impact analysis



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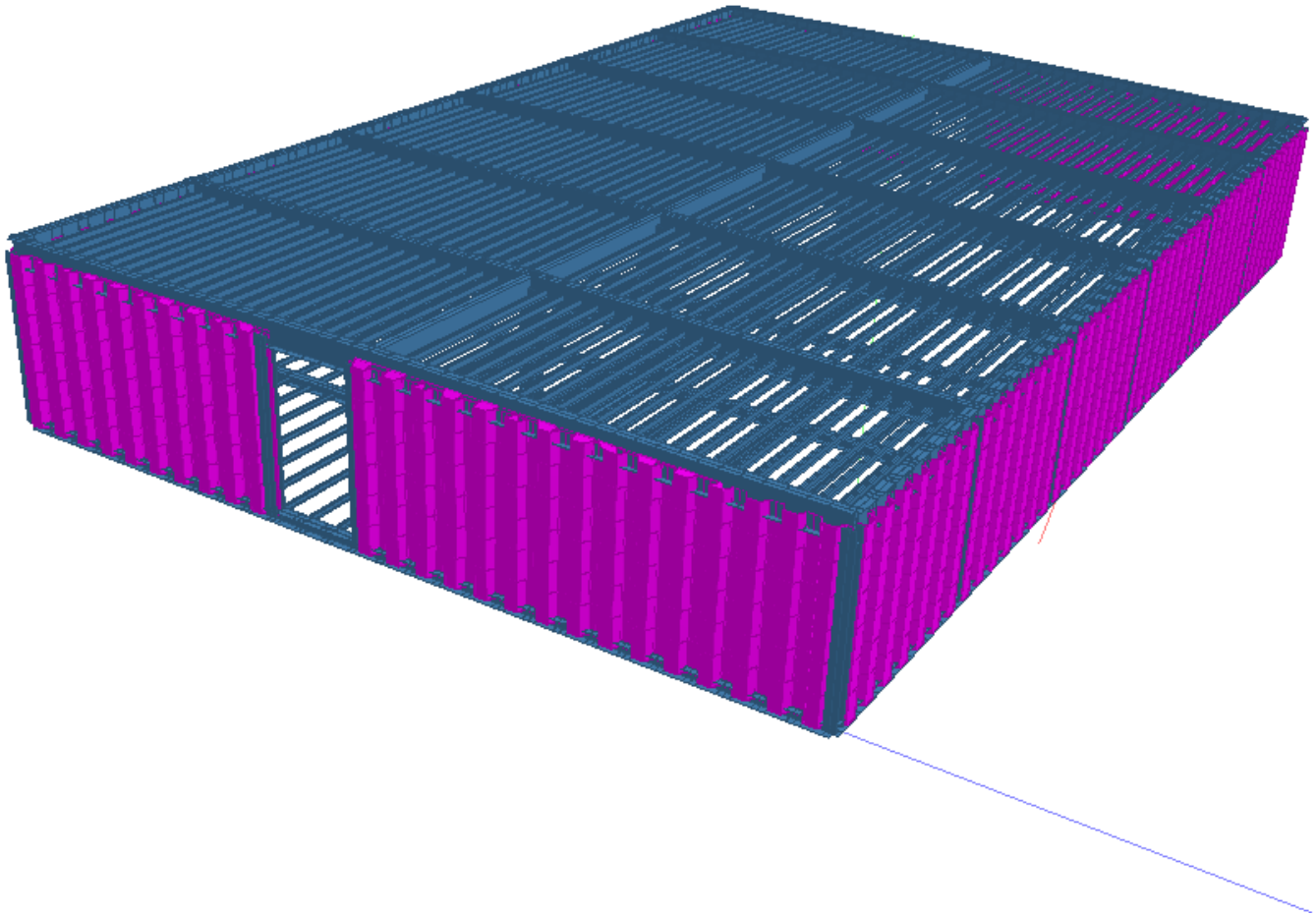
Blast resistant frame model & analysis



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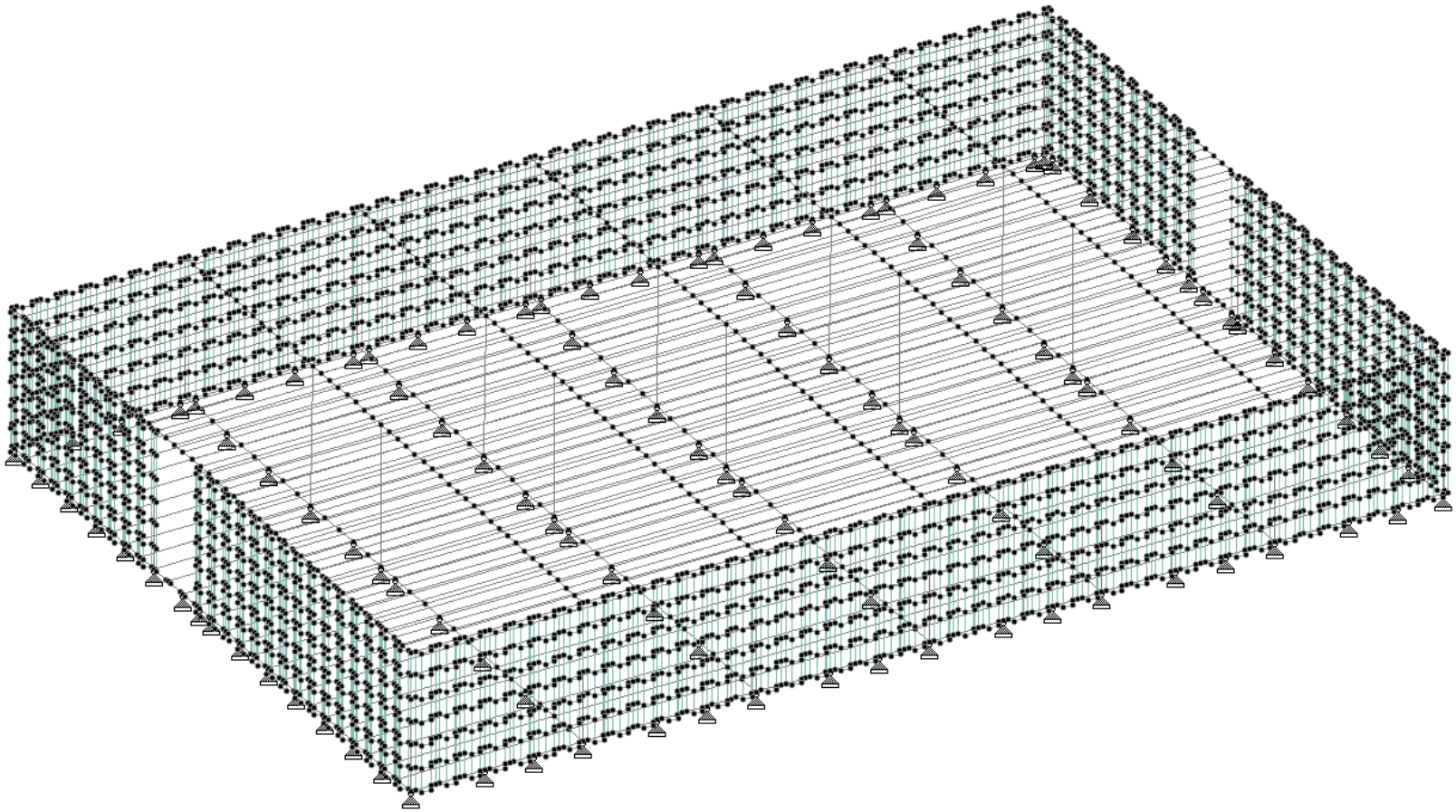
Blast resistant frame model & analysis



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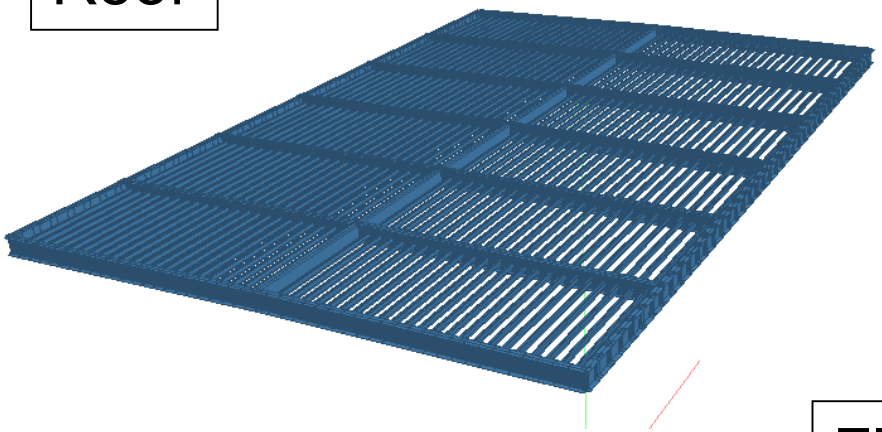
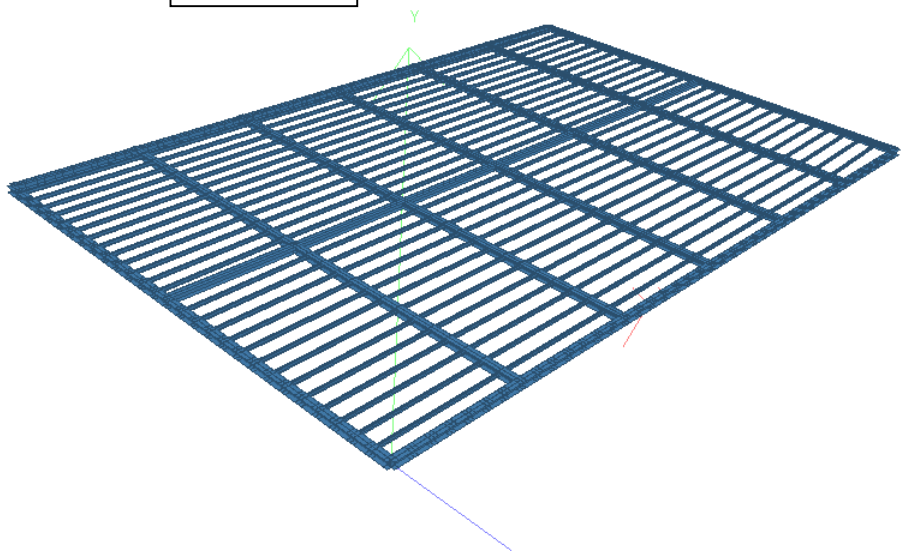
Blast resistant frame model & analysis

Roof



Floor



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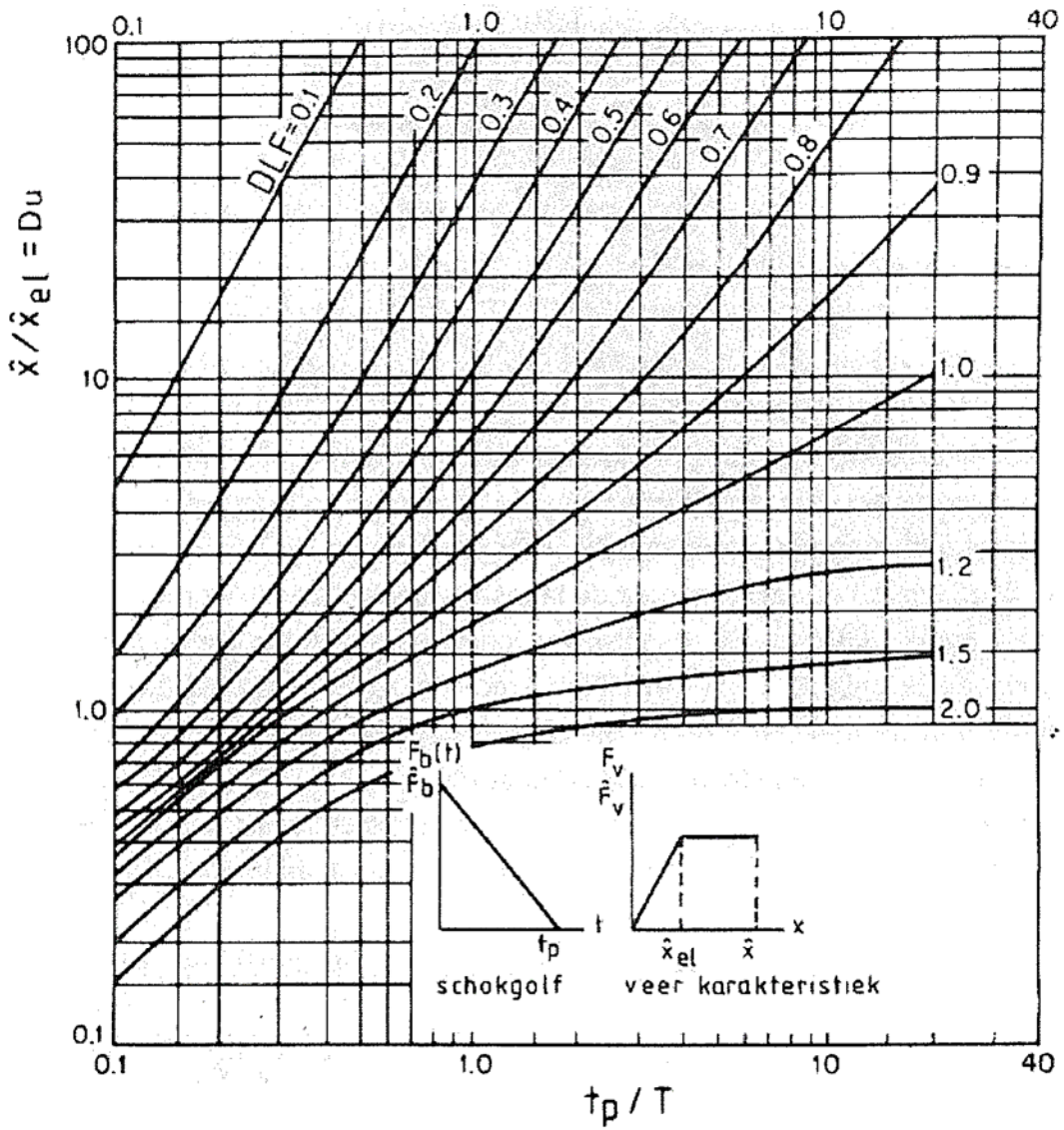
Blast resistant frame model & analysis



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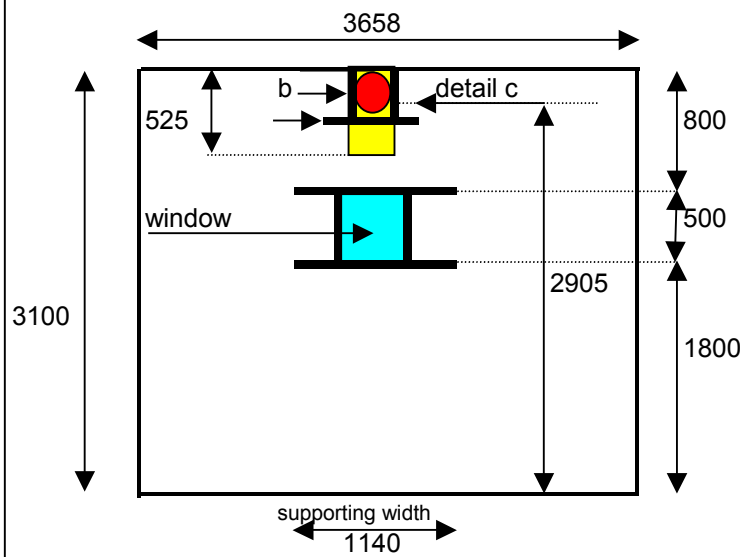
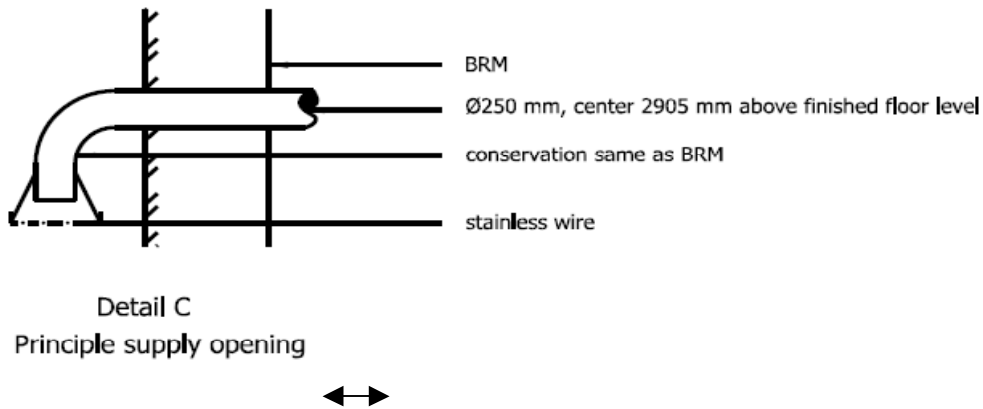
Design details

- Doors
- Windows
- Ducts
- Piping

HVAC 250 mm pipe mounted in corrugated wall





Detail C
Principle supply opening