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Dossier CMP Arles : 783	Page/*Sheet* 0.1
Client / *Customer* : MESSER *Engineered System N°* :	

1 RESERVOIR DE STOCKAGE LOX 1800MT
1 x 1800MT LOX STORAGE TANK

NOTE DE CALCUL SISMIQUE ET CHARGES GENIE CIVIL
EARTHQUAKE CALCULATION NOTE WITH LOADING FOR CIVIL ENGINEERING

1		28/07/04	HULIN	[signature]	28/07/04	CABRELLI	[signature]	28/07/04	LEBOUCQ	[signature]	
EDITION *EDITION N°*	REFERENCE *CLIENT REF.*	DATE	NOM *NAME*	SIGN.	DATE	NOM *NAME*	SIGN.	DATE	NOM *NAME*	SIGN.	ETAT D'AVANC. *STATUS*
		REDACTEUR *DRAWN UP BY*			VERIFICATEUR *CHECKED BY*			APPROBATEUR *APPROVED BY*			

Projet : *Project* ASU KOSICE	Classement CMP Arles : 783-NC01 *CMP Arles document N°*

N° CMP arles : 783 - NC 01

Item : 1 x 1800 MT LOX

Rev : 0

Page 0.2

Appareil / Item : 1 x 1800 MT LOX

Client : MESSER

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OBJET DES MODIFICATIONS :

(subject of modifications)

INDICE DE L'EDITION Edition n°	OBJET DE LA MODIFICATION (subject of modifications)
1	Premiere diffusion / First issue

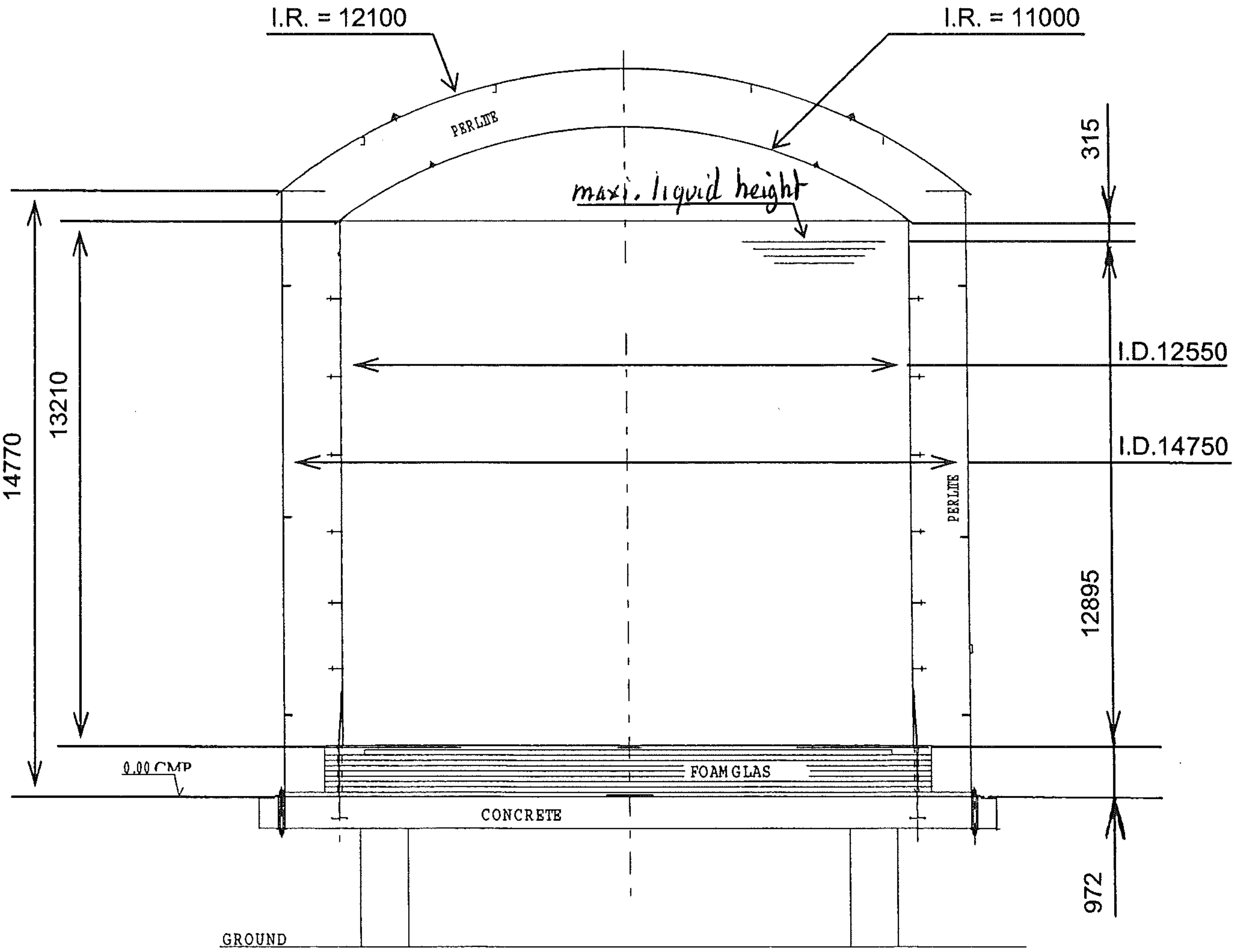
N° CMP arles : 783 - NC 01

Item : 1 x 1800 MT LOX

Rev : 0

GEOMETRIE DE L'APPAREIL :

Geometry of equipment (sketch)



LOADS ON STORAGE TANK SUPPORTING SLAB

1°) UNITS: Forces are expressed in metric tons
1 t = 1 metric ton force = Weight of a mass of 1000 Kg — 1 t = 9810 N
1 N = 1 Newton — 1 Mpa = 1,02E-02 t/m²

2°) DATA: **External casing (id)** — Dt = 14750 mm

Heights and thiknesses of shells

		H		Thk	
Bottom	V1 =	2110	mm	6.00	mm
↑	V2 =	2110	mm	6.00	mm
	V3 =	2110	mm	6.00	mm
	V4 =	2110	mm	6.00	mm
	V5 =	2110	mm	6.00	mm
	V6 =	2110	mm	6.00	mm
	V7 =	2110	mm	6.00	mm
	V8 =	0	mm	0.00	mm
	V9 =	0	mm	0.00	mm
	V10 =	0	mm	0.00	mm
↓	V11 =	0	mm	0.00	mm
Top	V12 =	0	mm	0.00	mm

Height for wind calculation Hv
18082 mm

Shell stiffeners

	Width		Thk		Qte
V1 =	150	mm	20.00	mm	3
V2 =	0	mm	0.00	mm	0

Roof (Inner radius)	DRe =	12100	mm	7.00	mm
Central part of the roof	dR =	3950	mm	10.00	mm
Roof beams (UPN 140)	D1 =	5000	mm		
	D2 =	10480	mm		
	D3 =	0	mm		
Flat bottom (Y/N) Y	DBe =	15050	mm	5.00	mm
Anchoring ring N	Le =	0	mm	0.00	mm
Stairs	Ms =	2550	Kg		
Top equipements.	Me =	1500	Kg		

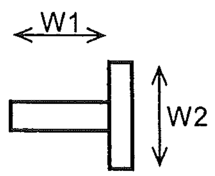
Inner vessel (id) — Di = 12550 mm
Service liquid height — Hl = 12895 mm

Mini yield strength
fty = 206.50 N/mm²

Heights and thiknesses of shells

		H		Thk	
Bottom	V1 =	1995	mm	8.00	mm
↑	V2 =	1995	mm	7.00	mm
	V3 =	1995	mm	6.00	mm
	V4 =	1995	mm	6.00	mm
	V5 =	1995	mm	6.00	mm
	V6 =	1995	mm	6.00	mm
	V7 =	1240	mm	6.00	mm
	V8 =	0	mm	0.00	mm
	V9 =	0	mm	0.00	mm
	V10 =	0	mm	0.00	mm
↓	V11 =	0	mm	0.00	mm
Top	V12 =	0	mm	0.00	mm

Shell stiffeners	W1	Thk W1		W2	Thk W2		Qty
type A	180.0	6.0	mm	100.0	8.0	mm	6
type B	0.0	0.0	mm	0.0	0.0	mm	0



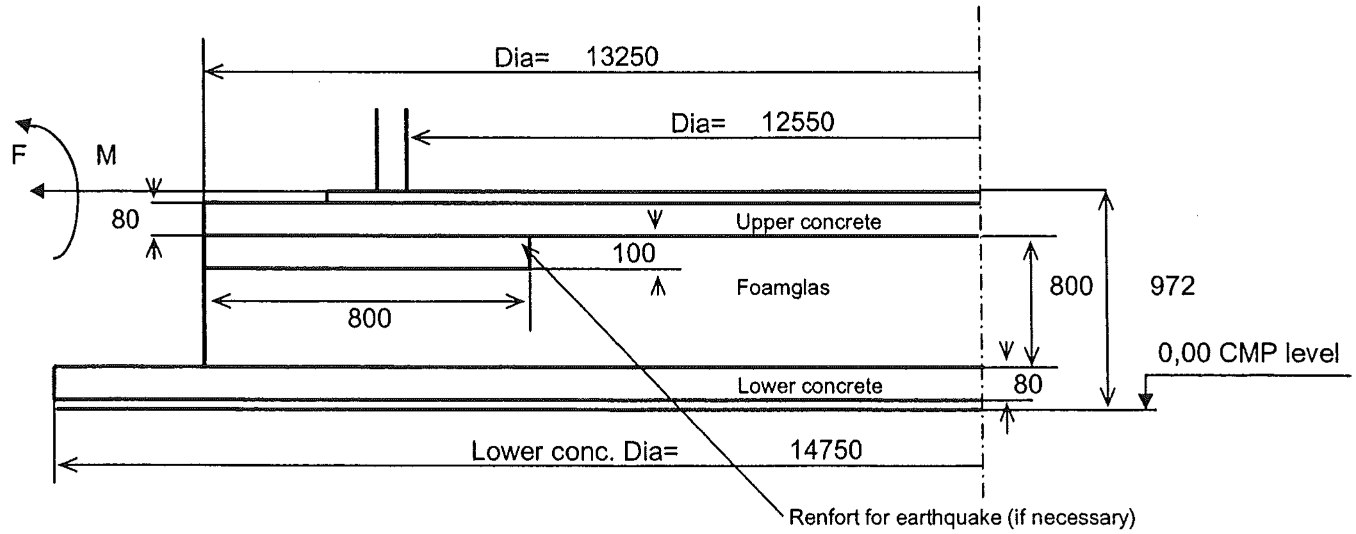
Roof (Inner radius)	DRi =	11000	mm	6.00	mm
Compression ring — Dia= 12600 mm		400.0	mm	15.00	mm
Bottom	DBi =	11320	mm	5.00	mm
Bottom annular ring	Li =	730	mm	7.00	mm
Accessories Piping	M3 =	1000	Kg		

2°) DATA: (Cont.)

Quantity, width and thikness of straps		n =	40	Wia = 100		Tha=	10	mm
	Mini yeld strength	Fby=	206.50	N/mm²				
Dia of the bottom insulation		Dbi	=	13250	mm			
Width and thikness of upper concrete renfort for earthquake (if any)		Wuc	=	800	mm	Thc=	100	mm
Densities	Steel	ds	=	8000	Kg/m^3			
	Perlite	dp	=	56	Kg/m^3			
	Liquid	dl	=	1140.0	Kg/m^3		Thk.	
	Upper concrete	dcs	=	2500	Kg/m^3	cs=	80	mm
	Lower concrete	dci	=	2500	Kg/m^3	ci=	80	mm
Foamglas								
	Density / thk	df	=	130	Kg/m^3	cf=	800	mm
	Minimum compressive strength	Mcs	=	0.69	Mpa			
	Safety factor in sismic load	Sf	=	2.00				
Pressure	Design	Dp	=	0.0200	Mpa			
	Test	Tp	=	0.0250	Mpa			
Wind velocity		ws	=	162	Km/h			
Shape factor		Sc	=	0.80				
Load of snow		sl	=	140	Kg/m²			

Seismic conditions : API 620 Appendix L with seismic zone: 2B, Importance factor I=1 and a soil S3

BOTTOM ISOLATION



3°) CALCULATION OF SEPARATE LOADS.

P1= Uplift force acting on the roof of the vessel under design condition
P1= (Di^2 x pi / 4) x Dp
P1= 12550^2 x pi/4 x 0.02
P1= 2474043 N — **P1 = 253 t**

P2= Uplift force acting on the roof of the vessel under test condition
P2= (Di^2 x pi / 4) x Tp
P2= 125502 x pi/4 x 0.03
P2= 3092554 N — **P2 = 316 t**

P3= Weight of inner vessel exept bottom

Shell		26.90 t
Shell stiffeners		3.63 t
roof		6.65 t
Compression ring		1.90 t
Piping		1.00 t
Total P3	=	**40 t**

P4= Weight of inner vessel bottom

Flat bottom		4.03 t
Annular ring bottom		1.53 t
Total P4	=	**6 t**

P5= Weight of external casing exept bottom

Shell		32.87 t
Shell stiffeners		3.37 t
roof		11.19 t
Roof beams		0.78 t
Stairs + Top equipments		4.05 t
Total P5	=	**53 t**

P6= Weight of external flat bottom vessel (if any)

Total P6 = 7.12 t

P7= Weight of perlite on the roof of the inner vessel
Volum of perlite 165 m^3 — **P7 = 10 t**

P8= Weight of components in the annular space between inner vessel and external casing

1	Volum of perlite	712 m^3	=	39.87 t
2	Volum of lower concrete	3 m^3	=	6.60
		P8	=	**46 t**

P9= Weight of bottom insulation

Volum of upper concrete	11.03 m^3	=	27.58 t
Volum of lower concrete	13.67 m^3	=	34.17 t
Volum of sismic renfort	3.13 m^3	=	7.82 t
Volum of foamglas	110.31 m^3	=	14.34 t
Total P9		=	**84 t**

P10= Weight of liquid in working conditions
Volum of liquid 1595 m^3 — **P10 = 1819 t**

P11= Weight of water during the test
Volum of liquid 1595 m^3 — **P11 = 1596 t**

4°) DATA FOR CIVIL ENGINEERING To be read with the Civil Engeneering drawing.

A = P3 + P7 - P1   B = P3 - P2   C = P4 + P6 + P9

4.1 °) FULL OF LIQUID WITHOUT GAZ PRESSURE:

F1	=	53.0	t	=	P5
F2	=	46.5	t	=	P8
F3	=	50.1	t	=	P3 + P7
F4	=	1915.7	t	=	C + P10
F5	=	0.0	t	=	0

4.2 °) FULL OF LIQUID WITH GAZ PRESSURE:

F1	=	53.0	t	=	P5
F2	=	46.5	t	=	P8
F3	=	0.0	t	=	If A<0: F3=0. If A>0: F3=A
F4	=	2168.7	t	=	C + P10 + P1
F5	=	202.9	t	=	If A<0: F5=A. If A>0: F5=0

4.3 °) HYDROPNEUMATIC TEST:

F1	=	53.0	t	=	P5
F2	=	6.6	t	=	P8 + weight of perlite
F3	=	0.0	t	=	If B<0: F3=0. If B>0: F3=B
F4	=	2008.7	t	=	C + P11 + P2
F5	=	275.9	t	=	If B<0: F5=B. If B>0: F5=0

4.4 °) LOADS DUE TO THE SNOW: To be added to loads 4.1 , 4.2 & 4.3 cases

F1 = 25.0 t

4.5 °) LOADS DUE TO THE WIND: To be added to loads 4.1 , 4.2 & 4.3 cases

SHEAR FORCE	=	27.0	t
MOMENT at 0.00 CMP	=	244.1	tm

4.6 °) LOADS DUE TO EARTHQUAKE: To be added to loads 4.1 , 4.2 & 4.3 cases

SHEAR FORCE	=	233	t
MOMENT at 0.00 CMP	=	1539.9	tm

F5 = 9.80 t per strap x 40 = 391.8 t

5 °) MASSES AND HEIGHT OF CENTROIDS

5.1) Mass and height of centroids for inner vessel components

Shell and stiffeners of inner tank	m2	=	30.53 t
Height of centroid of the shell	H2	=	6299 mm
Roof of the inner vessel	m3	=	8.55 t
Height of centroid of the roof	H3	=	14200 mm
Flat bottom of the inner tank	m4	=	5.56 t

5.2) Mass and height of centroids for outer casing components at the level of the bottom of outer casing.

Shell and stiffeners of outer casing	m5	=	36.24 t
Height of centroid of the shell	H5	=	7387.5 mm
Roof and roof beams	m6	=	11.97 t
Height of centroid of the roof	H6	=	16029 mm
Perlite on the roof of the vessel	m7	=	10.00 t
Centroid of the perlite in th roof	H7	=	16029 mm
Perlite in the annular space	m8	=	39.87 t
Centroid of the perlite in this space	H8	=	7623 mm
Bottom of the casing	P6	=	7.12 t
Stairs	m10	=	2.55 t
Centroid fo the stairs	H10	=	7388 mm
Accessories on the casing top	m11	=	1.50 t
Centroid of the accessories	H11	=	17283 mm

5.3) Mass and height of centroids of supporting slab

Weight of concrete	m12	=	34.17 t
Height of centroid concrete	H12	=	40 mm
Weight of bottom insulation + upper concrete	m13	=	49.74 t
Height of centroid of bottom insulation	H13	=	779 mm
Distance between top level of slab and 0.00 CMP	H14	=	960 mm

NOTE : Some factors in formulas acc. to API 620 have been changed in order to obtain correct results in métric units.

A) SEISMIC ZONE : = 2B

V=	Max. volume of tank contents	=	1595.1	m^3
G=	Density of tank contents	=	1140	Kg/m^3
Z=	Seismic zone factor from Table L-2	=	0.2	-
I=	Importance factor	=	1.00	-
p=	Internal design pressure	=	0.0200	Mpa
Xs=	Height from the bottom of the tank shell to the center of gravity of the shell	=	6.2578	m
Wr+s=	Mass of tank shell and roof including attachements	=	40084	Kg
Ht=	Total height of tank shell	=	13.210	m
D=	Internal diameter of tank	=	12.550	m
H=	Maximum design product height	=	12.895	m
S=	Site coefficient from Table L-3	=	1.5	for **S3** Type
g=		=	9.81	M/s^2
Fby=	Minimum spécified yeld strength of shell and bottom plate	=	206.50	N/mm^2
tb=	Thickness of bottom plate under the shell	=	7.00	mm
t=	Thickness of bottom shell course	=	8.00	mm
n=	Number of anchorages	=	40	
Sa=	Section of anchorages	=	1000.00	mm^2
Da=	Diameter of anchorcircle	=	12.700	m
X=	Width of the bottom annular plate (inside)	=	0.665	m

B) FACTORS :(According to API 620 curves)

D/H=	12.55 / 12.9 =		**0.97**	
Wt=	1595.14 x 1140 =		**1818300**	Kg
FIGURE L-2	W1 / Wt	=	**0.82**	
	W2 / Wt	=	**0.24**	
W1=	Wt x 0.82	=	**1491675**	Kg
W2=	Wt x 0.24	=	**437104**	Kg
FIGURE L-3	X1 / H	=	**0.41**	
	X2 / H	=	**0.73**	
X1=	12.90 x 0.41	=	**5.27**	m
X2=	12.90 x 0.73	=	**9.44**	m
FIGURE L-4	k = 0.6			
T=	k x $D^{1/2}$	=	**3.85**	
C1=		=	**0.60**	
C2=	0,75x S/T if T<4,5 or 3,375x S/T^2	=	**0.2922**	

C) AT THE BOTTOM OF THE TANK

MOMENT

M= Z x I x (C1 x Wr + s x Xs + C1 x W1 x X1 + C2 x W2 x X2) x g
M= 0.2 x 1 x [(0.6 x 40083.86 x 6.26) + (0.6 x 1491674.91 x 5.27)
+ (0.29 x 437104.09 x 9.44)] x 9.81

M= 11919172 Nm

SHEAR FORCE

F= Z x I x (C1 x Wr + s + C1 x W1 + W2 x C2) x g
F= 0.2 x 1 x (0.6 x 40083.86 + 0.6 x 1491674.91 + 437104.09 x 0.29) x 9.81

F= **2053780 N**

D) WEIGHT OF THE TANK CONTENTS RESISTING SHELL OVERTURNING

WL= 23.84 x tb x (Fby x G x H)$^{1/2}$
WL= 23.84 x 7 x (206.5 x 1140 x 12.9)^(1/2)

WL= **290755 N/m**

WL< 1,25 x G x H x D x 9,81
WL< 1.25 x 1140 x 12.9 x 12.55 x 9.81
WL< **2262293 N/m** THEN OK

tb<= MAX(53,35,t) 7.0 <= 8.0 THEN OK

X > 2,79.10^{-03} x WL / (G x H)
X= 0.67 > 0.00279 x 290755.15 / (1140 x 12.9)
X= 0.67 > **0.0552 m** THEN OK

E) SHELL COMPRESSION

Max. longitudinal compression force at the bottom of the shell:

b= Wr + s x g / (PI x D) + (1,273 x M / D²)
b= 40083.8641985722 x 9.81 / (PI x 12.55) + (1.273 x 11919172.23 / 12.55²)

b= **106309 N/m**

Compression stress:

b x 10^3 / t = 106309.09 x 1000 / 8
F= **13288637 N/m² = 13.29 Mpa**

According to API 620 appendix L chap L-5-3 F should be less than Fa and in any case less than Fa = Fby / 2.

Value of Fa depends of the ratio of R = 157,08746 x G x H x D² / t² in métric units.

R = 5682.97

If R <= 6894.76 Fa= 33,094834 x t / D + 7,4931208 x (G x H)$^{1/2}$
Fa= **49.83 Mpa**

If R > 6894.76 Fa = 82,737084 x t / D
Fa = **0.00 Mpa**

Then Fa = **49.83 Mpa >13.29 Mpa** THEN OK

Fa =< 0,5xFby =< **0.5 x 206.5 = 103.25 Mpa** THEN OK

F) ANCHORAGE:

UPLIFT DUE INTERNAL PRESSURE WHITHOUT INNER TANK DEAD WEIGHT

P= p x PI / 4 x D² x 10^6 - (Wr + s)x 9,81
P= 0.02 x PI/4 x 12.55² x 1000000 - (40083.86) x 9.81

P= **2080821** N

UPLIFT DUE TO EARTHQUAKE

E= 1,273 x M / D²
E= 1.273 x 11919172.23 / 12.55²

E= **96336** N/m

UPLIFT FORCE PER ANCHORAGE

Due to internal pressure

Ap= P / n
Ap= 2080820.78 / 40

Ap= **52021 N**

Stress due to internal pressure

Ap/Sa= 52020.52 / 1000
Ap/Sa= **52.02 N/mm²**

NOTE :
The straps calculation with 1.5 x (gas pressure of 200mbar + seismic loading) is not considered.

Due to earthquake

Ae= (E x PI x Da) / n
Ae= (96335.65 x 3.14 x 12.7) / 40

Ae= **96091** N

Stress due to earthquake

Ae/Sa= 96090.54 / 1000
Ae/Sa= **96.09 N/mm²**

ACTUAL STRESS

Ae/sa+Ap/sa= 96.09 + 52.02 **N/mm²**
Ae/sa+Ap/sa= **148.11 N/mm²**

ALLOWABLE TENSIL STRESS (90% yield strength)

Fby = **185.85 N/mm²** **THEN OK**

G) ADDITIONAL CONSIDERATION

HEIGHT OF SLOSHING WAVE:

d= 1,124 x Z x I x C2 :
d= 1.124 x 0.2 x 1 x 0.29 x 3.85^2 x tanh (4.77 x (12.9 / 12.55)^(1/2)

[d= 0.3048 m] => 0.3048 (Minimum supplementary height of inner shell)

ACTUAL SUPPLEMENTARY HEIGHT:

Ha= Ht-H
Ha= 13.21 - 12.9
[Ha= 0.315] > 0.305 THEN OK

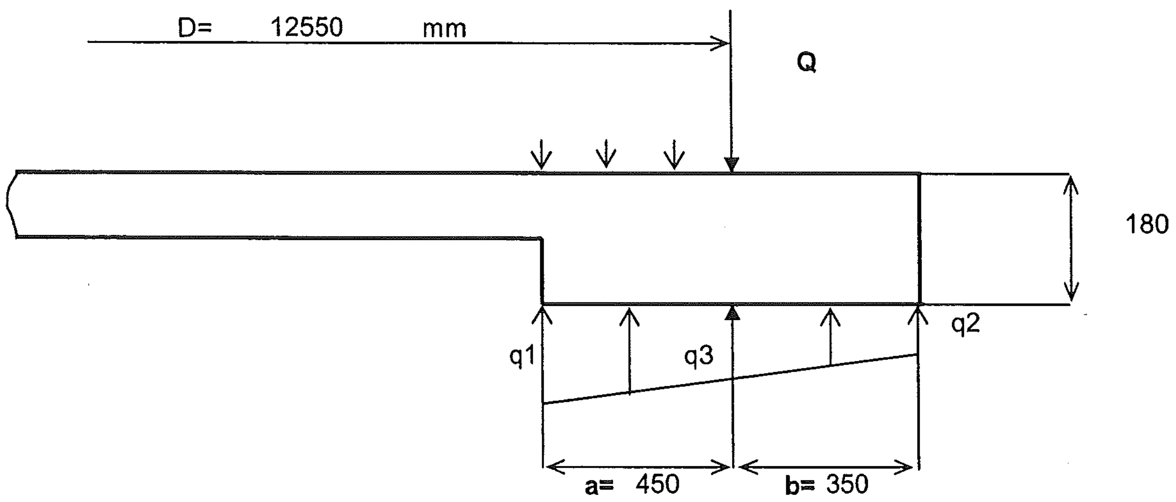
STRESSES IN CONCRETE RING AND FOAMGLAS

In the concrete ring

Load per unit of length

Q = (Wr + S) x g / Pi x D + 4 x M / pi x D^2
Q = 106327 N

p = G x g x H
p = 144210 N/m²



C1 = q1 + q2
= (2 / (a + b)) x (Q + a x p)
C1 = 428054 N/m²

C2 = q1 + 2 x q2
= (6 x a / (a+ b)²) x (Q + a x p /2)
C2 = 585455 N/m²

q2 = C2 - C1
q2 = 157401 N/m²
q1 = C1 - q2
q1 = 270654 N/m²

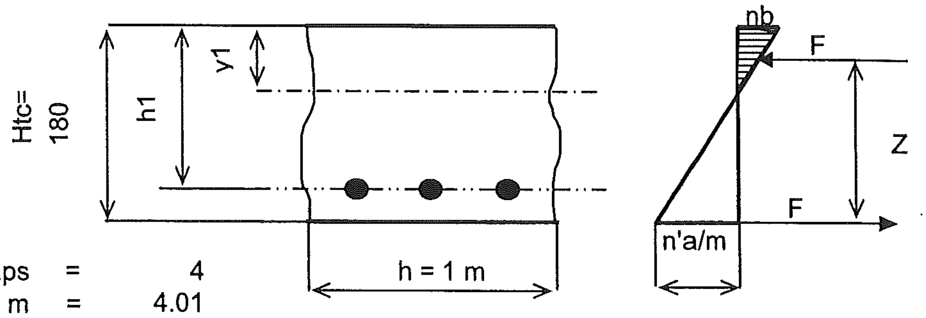
q3 = (q1 x b + q2 x a) / (a + b)
q3 = 206949 N/m²

Flexural moment in the concrete ring per unit of length

Mf = b² / 6 x (2 x q2 + q3)
Mf = 10652 N.m/m

STRESSES IN CONCRETE AND RENFORCING BARS

dcs = Upper concrete density = 2500 Kg/m^3
n'a = Tensil stress in iron bars
nf = Compression stress in concrete
m = Ratio of young's moduli of stell to concrete
m = **15**



Quantity of bars between two straps	=	4	
Quantity of bars per m	=	4.01	
Dia of bars	=	16	mm
h1	=	150	mm
Section of bar	=	201.06	**mm²**
Total section of tensile stressed bars on the length 1 m **w'**	=	**806.30**	**mm²**

Compression force on concrete = tensile force in the bars = F

Mo = h1 / 2 x m x w'
Mo = 6.20

Nu = 1 / 2 x ((1 + 4 x Mo)$^{1/2}$) -1)
Nu = 2.040

y1 = h1 / (1 + Nu)
y1 = 0.049 m

Z = h1 - y1 / 3
Z = 0.134 m

F = M f / Z
F = 79762 N/m

n'a = F / w'
n'a = 98.92 N/mm²

nb = 2 x F / y1
nb = 3.23 N/mm²

Allowable stresses

n'a	**98.92**	**=<**	**172**	**N/mm²**	**Then OK**
nb	**3.23**	**=<**	**7.50**	**N/mm²**	**Then OK**

Compression in the foamglas under the concrete ring

P = (max of q1 and q2) + dcs x g x Htc
P = 275068 N/m²
P = 0.27507 N/mm²

Proper weight of the foamglas layers

P'=foamglas thk x g x ro'''
P'= 700 X 9.81 X 0.13
P'= 0.0009 MPa

Total stress at the base of Faomglas

St= P+P'
St= 0.2760 **MPa**

Allowable compressive strength:	**0.69**	**MPa**
Safety factor:	**2.00**	

Calculated safety factor = 2.50 Then OK

8°) SHEAR FORCE AND MOMENT AT 0,00 CMP DUE TO THE EARTHQUAKE

8.1) Outer casing:

Maximum horizontal shear force at 0,00 CMP.

Fe= (36.24 + 11.97 + 10 + 39.87 + 7.12 + 2.55 + ')x 0.12 x 9810

Fe= 128600 N

Maximum moment at 0,00 CMP.

Me= [(36.24 x 7.39) + (11.97 x 16.03) + (10 x 16.03) + (39.87 x 7.62)
+ (2.55 x 7.39) + (1.5 x 17.28)] x 0.6 x 0.2 x 9810

Me= 1140132 Nm

8.2) Inner vessel:

Maximum horizontal shear force at 0,00 CMP.

Fb=F (page 10) = 2053780 N

Maximum moment at 0,00 CMP.

Mb = M + F x Epi

Mb = 11919172 + 2053780 x 0.97

Mb = 13915447 Nm

8.3) Isolation and concrete under the inner tank:

Maximum horizontal shear force at 0,00 CMP.

Pi = P4 + P9
Pi = 5560 + 84000 **Pi = 89560 Kg**
Fi = Pi x C1 x Z x 9.81
Fi = 89560 x 0.6 x 0.2 x 9.81
Fi = 105431 N

Maximum moment at 0,00 CMP.

Mi = Fi x Epi / 2
Mi = 105431 x 0.49
Mi = 51239 Nm

8.4) TOTAL SHEAR FORCE AND MOMENT AT 0,00 CMP DUE TO THE EARTHQUAKE

FT = Fb + Fi + Fe
FT = 2053780 + 105431 + 128600
FT = 2287811 N

FT = 233 t

MT = Mb + Mi + Me
MT = 13915447 + 51239 + 1140132.32
MT = 15106818 Nm

MT = 1540 tm

ANCHOR BOLTS FOR OUTER CASING :

Data :

Anchor bolt diameter :	D3 =	14.55	m	
Anchor bolt number :	n =	16		
Anchor bolt section :	s =	1040	mm²	(M42)
Allowable stress in anchor bolt :	=	165.5	MPa	
Mass of shell and stiffeners of outer casing :	m5 =	36235	kg	
Mass of roof and roof beams :	m6 =	11966	kg	
External casing diameter :	D =	14750	mm	
Outer casing internal pressure :	p =	0.001	Mpa	
Maximum bending moment at the base of the shell :	M3 =	1140132	N.m	

Uplift force per anchor bolt due to seism :

uf1 = 1 / n x 4 x M3 / D3
uf1 = 1 / 16 x 4 x 1140132.32 / 14.55

uf1 = 19590 N

Uplift force per anchor bolt due to seism + internal pressure :

L = p x pi x D² / 4
L = 0.001 x pi x 14750² / 4

L = 170873 N

uf2 = 1 / n x [(4 x M3 / D3) + L - (m5 + m6) x g]
uf2 = 1 / 16 x [(4 x 1140132.32 / 14.55) + 170873.19 - (36235 + 11966) x 9.81)]

uf2 = 716 N

Tensile stress in anchor bolt :

Sp = MAX(uf1,uf2) / s
Sp = 19589.9 / 1040

Sp = 18.84 MPa < 165.50 MPa THEN OK