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Dossier CMP Arles : 783

Client / *Customer* **: MESSER**

Engineered System N° :

1 RESERVOIR DE STOCKAGE LIN 1000MT

1 x 1000MT LIN 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 : *CMP Arles document N°* 783-NC101

CMP ARLES

N° CMP arles : 783 - NC101

Item : 1 x 1000 MT LIN

Rev : 0

Page 0.2

Appareil / Item : 1 x 1000 MT LIN

Client : MESSER

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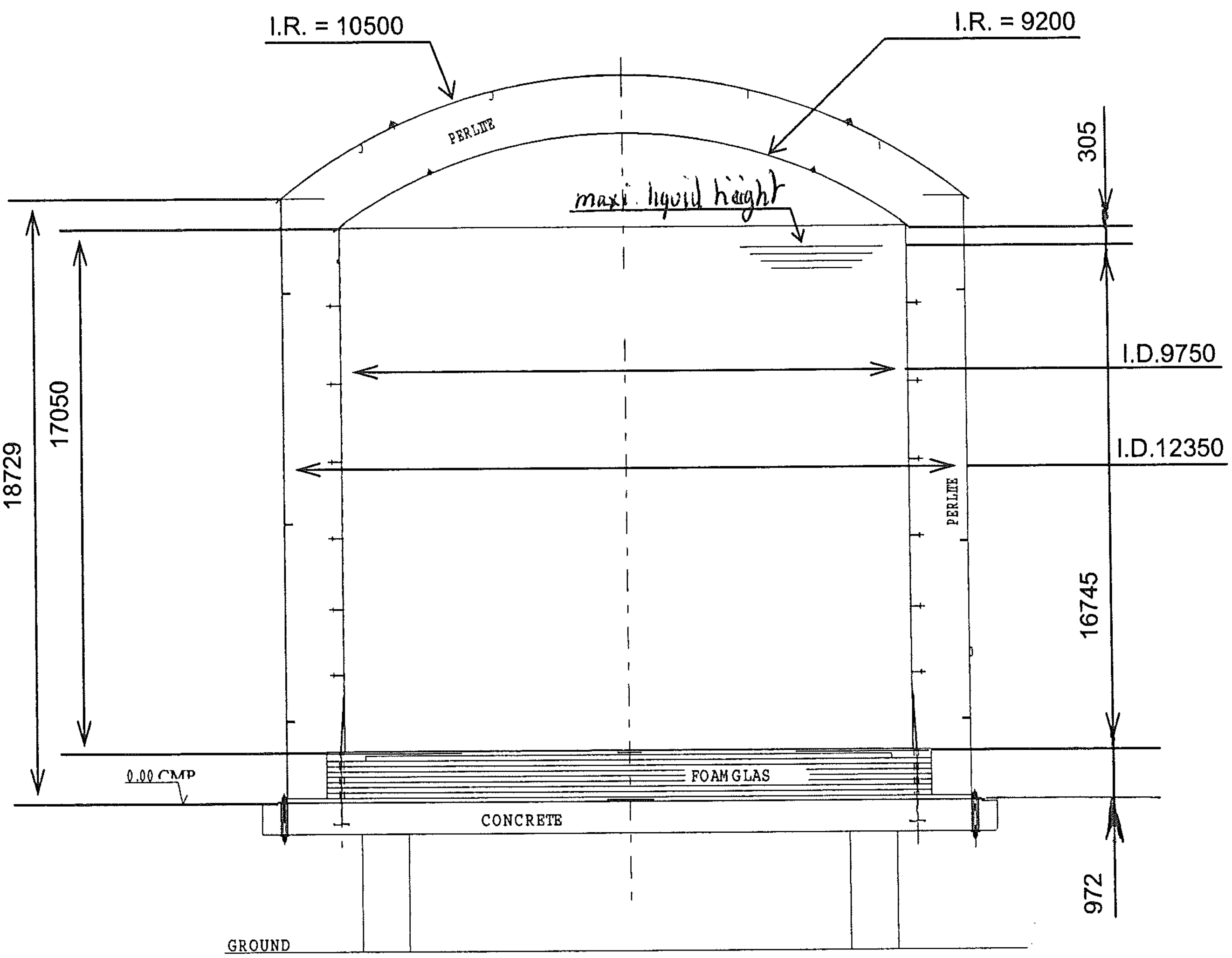
OBJET DES MODIFICATIONS :

(subject of modifications)

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

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 = 12350 mm

Heights and thiknesses of shells

		H		Thk	
Bottom	V1 =	2081	mm	6.00	mm
	V2 =	2081	mm	6.00	mm
	V3 =	2081	mm	6.00	mm
	V4 =	2081	mm	6.00	mm
	V5 =	2081	mm	6.00	mm
	V6 =	2081	mm	6.00	mm
	V7 =	2081	mm	6.00	mm
	V8 =	2081	mm	6.00	mm
	V9 =	2081	mm	6.00	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
21542 mm

Shell stiffeners		Width		Thk		Qte
	V1 =	150	mm	20.00	mm	4
	V2 =	0	mm	0.00	mm	0

Roof (Inner radius)	DRe =	10500	mm	6.00	mm
Central part of the roof	dR =	3950	mm	10.00	mm
Roof beams (UPN 140)	D1 =	5000	mm		
	D2 =	10000	mm		
	D3 =	0	mm		
Flat bottom (**Y/N**) Y	DBe =	12600	mm	5.00	mm
Anchoring ring N	Le =	0	mm	0.00	mm
Stairs	Ms =	2700	Kg		
Top equipements.	Me =	1500	Kg		

Inner vessel (id) Di = 9750 mm

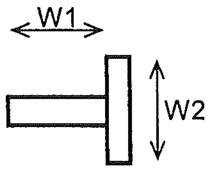
Service liquid height Hl = 16745 mm

Mini yield strength **fty** = 206.50 N/mm²

Heights and thiknesses of shells

		H		Thk	
Bottom	V1 =	1995	mm	6.00	mm
	V2 =	1995	mm	6.00	mm
	V3 =	1995	mm	5.00	mm
	V4 =	1995	mm	5.00	mm
	V5 =	1995	mm	5.00	mm
	V6 =	1995	mm	5.00	mm
	V7 =	1995	mm	5.00	mm
	V8 =	1995	mm	5.00	mm
	V9 =	1090	mm	5.00	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	160.0	5.0	mm	80.0	5.0	mm	10
type B	0.0	0.0	mm	0.0	0.0	mm	0



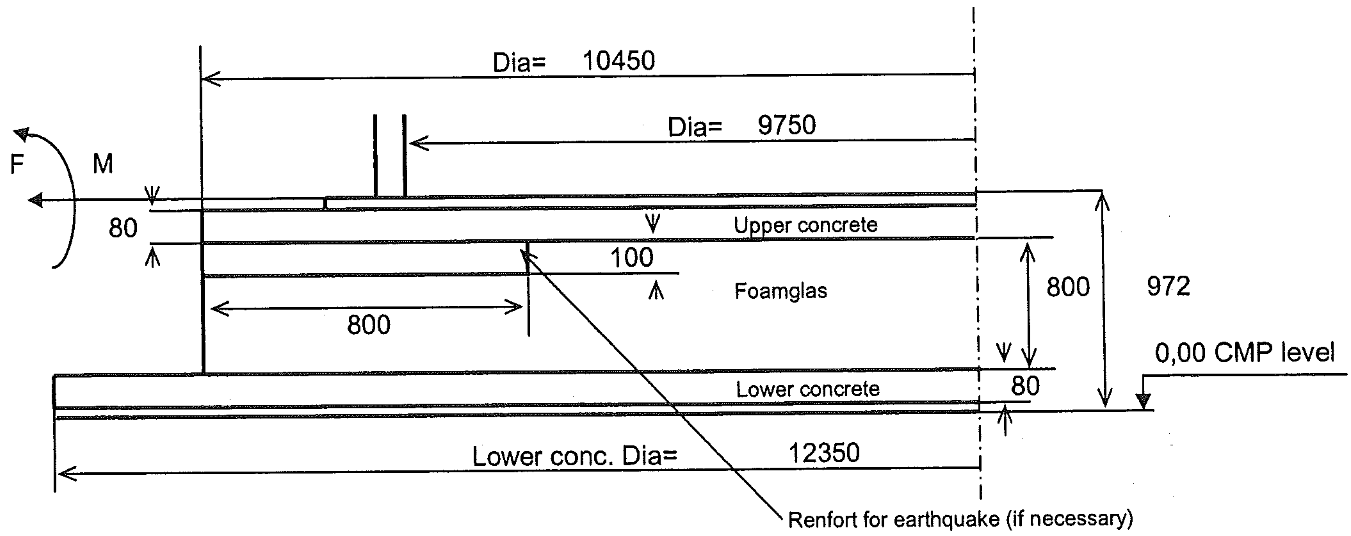
Roof (Inner radius)	DRi =	9200	mm	5.00	mm
Compression ring Dia= 9800 mm		260.0	mm	15.00	mm
Bottom	DBi =	8520	mm	5.00	mm
Bottom annular ring	Li =	730	mm	7.00	mm
Accessories Piping	M3 =	1000	Kg		

2°) DATA: (Cont.)

Quantity, width and thikness of straps		n = 32	Wia = 100		Tha=	10	mm
Mini yeld strength		Fby= 206.50	N/mm²				
Dia of the bottom insulation		Dbi =	10450	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 =	812.0	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= 9750^2 x pi/4 x 0.02
P1= 1493238 N **P1 = 153 t**

P2= Uplift force acting on the roof of the vessel under test condition
P2= (Di^2 x pi / 4) x Tp
P2= 97502 x pi/4 x 0.03
P2= 1866548 N **P2 = 191 t**

P3= Weight of inner vessel exept bottom

Shell		21.88 t
Shell stiffeners		3.01 t
roof		3.30 t
Compression ring		0.96 t
Piping		1.00 t
Total P3	=	**30 t**

P4= Weight of inner vessel bottom

Flat bottom		2.28 t
Annular ring bottom		1.18 t
Total P4	=	**3 t**

P5= Weight of external casing exept bottom

Shell		34.90 t
Shell stiffeners		3.77 t
roof		6.88 t
Roof beams		0.75 t
Stairs + Top equipments		4.20 t
Total P5	=	**51 t**

P6= Weight of external flat bottom vessel (if any) **Total P6 = 4.99 t**

P7= Weight of perlite on the roof of the inner vessel
Volum of perlite 125 m˘ **P7 = 7 t**

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

1 Volum of perlite	862 m˘		=	48.25 t
2 Volum of lower concrete	3 m˘		=	6.80
		P8	=	**55 t**

P9= Weight of bottom insulation

Volum of upper concrete	6.86 m˘		=	17.15 t
Volum of lower concrete	9.58 m˘		=	23.96 t
Volum of sismic renfort	2.43 m˘		=	6.06 t
Volum of foamglas	68.61 m˘		=	8.92 t
		Total P9	=	**57 t**

P10= Weight of liquid in working conditions
Volum of liquid 1250 m˘ **P10 = 1016 t**

P11= Weight of water during the test
Volum of liquid 1250 m˘ **P11 = 1251 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	=	51.0	t	=	P5
F2	=	55.1	t	=	P8
F3	=	37.1	t	=	P3 + P7
F4	=	1081.4	t	=	C + P10
F5	=	0.0	t	=	0

4.2 °) FULL OF LIQUID WITH GAZ PRESSURE:

F1	=	51.0	t	=	P5
F2	=	55.1	t	=	P8
F3	=	0.0	t	=	If A<0: F3=0. If A>0: F3=A
F4	=	1234.4	t	=	C + P10 + P1
F5	=	115.9	t	=	If A<0: F5=A. If A>0: F5=0

4.3 °) HYDROPNEUMATIC TEST:

F1	=	51.0	t	=	P5
F2	=	6.8	t	=	P8 + weight of perlite
F3	=	0.0	t	=	If B<0: F3=0. If B>0: F3=B
F4	=	1507.4	t	=	C + P11 + P2
F5	=	160.9	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 = 18.0 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	=	290.8	tm

4.6 °) LOADS DUE TO EARTHQUAKE:

To be added to loads 4.1 , 4.2 & 4.3 cases

SHEAR FORCE	=	142	t
MOMENT at 0.00 CMP	=	1223.9	tm

F5 = 12.51 t per strap x 32 = 400.5 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	=	24.88 t
Height of centroid of the shell	H2	=	8268 mm
Roof of the inner vessel	m3	=	4.26 t
Height of centroid of the roof	H3	=	17756 mm
Flat bottom of the inner tank	m4	=	3.46 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	=	38.67 t
Height of centroid of the shell	H5	=	9367 mm
Roof and roof beams	m6	=	7.64 t
Height of centroid of the roof	H6	=	19738 mm
Perlite on the roof of the vessel	m7	=	7.00 t
Centroid of the perlite in th roof	H7	=	19738 mm
Perlite in the annular space	m8	=	48.25 t
Centroid of the perlite in this space	H8	=	9622 mm
Bottom of the casing	P6	=	4.99 t
Stairs	m10	=	2.70 t
Centroid fo the stairs	H10	=	9367 mm
Accessories on the casing top	m11	=	1.50 t
Centroid of the accessories	H11	=	20743 mm

5.3) Mass and height of centroids of supporting slab

Weight of concrete	m12	=	23.96 t
Height of centroid concrete	H12	=	40 mm
Weight of bottom insulation + upper concrete	m13	=	32.14 t
Height of centroid of bottom insulation	H13	=	781 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	=	1250.2	m^3	
G= Density of tank contents	=	812	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	=	8.2329	m	
Wr+s= Mass of tank shell and roof including attachements	=	30142	Kg	
Ht= Total height of tank shell	=	17.050	m	
D= Internal diameter of tank	=	9.750	m	
H= Maximum design product height	=	16.745	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	=	6.00	mm	
n= Number of anchorages	=	32		
Sa= Section of anchorages	=	1000.00	mm^2	
Da= Diameter of anchorcircle	=	9.900	m	
X= Width of the bottom annular plate (inside)	=	0.665	m	

B) FACTORS :(According to API 620 curves)

D/H=	9.75 / 16.75 =		**0.58**	
Wt=	1250.21 x 812 =		**1015000**	Kg
FIGURE L-2	W1 / Wt	=	**0.89**	
	W2 / Wt	=	**0.14**	
W1=	Wt x 0.89	=	**903092**	Kg
W2=	Wt x 0.14	=	**145976**	Kg
FIGURE L-3	X1 / H	=	**0.44**	
	X2 / H	=	**0.81**	
X1=	16.75 x 0.44	=	**7.39**	m
X2=	16.75 x 0.81	=	**13.50**	m
FIGURE L-4	k = 0.6			
T=	$k \times D^{1/2}$	=	**3.39**	
C1=		=	**0.60**	
C2=	0,75x S/T if T<4,5 or 3,375x S/T^2	=	**0.3315**	

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 30142.15 x 8.23) + (0.6 x 903092.29 x 7.39)
+ (0.33 x 145976.34 x 13.5)] x 9.81

M= 9432625 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 30142.15 + 0.6 x 903092.29 + 145976.34 x 0.33) x 9.81

F= **1193552 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 812 x 16.75)^(1/2)

WL= **279631 N/m**

WL< 1,25 x G x H x D x 9,81
WL< 1.25 x 812 x 16.75 x 9.75 x 9.81
WL< **1625642 N/m** THEN OK

tb<= MAX(53,35,t) 7.0 <= 6.0 if it is not the case; see the following check

X > 2,79.10^{-03} x WL / (G x H)
X= 0.67 > 0.00279 x 279630.74 / (812 x 16.75)
X= 0.67 > **0.0574 m** THEN OK

E) SHELL COMPRESSION

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

$b = Wr + s \times g / (PI \times D) + (1{,}273 \times M / D^2)$

$b = 30142.1521148468 \times 9.81 / (PI \times 9.75) + (1.273 \times 9432624.79 / 9.75^2)$

b= **135968 N/m**

Compression stress:

$b \times 10^3 / t = 135967.66 \times 1000 / 6$

F= **22661277 N/m² = 22.66 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 $R = 157{,}08746 \times G \times H \times D^2 / t^2$ in métric units.

R = 5640.13

If R <= 6894.76 — $Fa = 33{,}094834 \times t / D + 7{,}4931208 \times (G \times H)^{1/2}$

Fa= **48.00 Mpa**

If R > 6894.76 — $Fa = 82{,}737084 \times t / D$

Fa = **0.00 Mpa**

Then Fa = **48.00 Mpa >22.66 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

$P = p \times PI / 4 \times D^2 \times 10^6 - (Wr + s) \times 9{,}81$
$P = 0.02 \times PI/4 \times 9.75^2 \times 1000000 - (30142.15) \times 9.81$

P= **1197544** **N**

UPLIFT DUE TO EARTHQUAKE

$E = 1{,}273 \times M / D^2$
$E = 1.273 \times 9432624.79 / 9.75^2$

E= **126314** **N/m**

UPLIFT FORCE PER ANCHORAGE

Due to internal pressure

Ap= P / n
Ap= 1197543.75 / 32

Ap= **37423** **N**

Stress due to internal pressure

Ap/Sa= 37423.24 / 1000
Ap/Sa= **37.42** **N/mm²**

Due to earthquake

Ae= (E x PI x Da) / n
Ae= (126314.07 x 3.14 x 9.9) / 32

Ae= **122768** **N**

Stress due to earthquake

Ae/Sa= 122768.46 / 1000
Ae/Sa= **122.77** **N/mm²**

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

ACTUAL STRESS

Ae/sa+Ap/sa= 122.77 + 37.42 **N/mm²**
Ae/sa+Ap/sa= **160.19** **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 0.33 x 3.39² x tanh (4.77 x (16.75 / 9.75)^(1/2)

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

ACTUAL SUPPLEMENTARY HEIGHT:

Ha= Ht-H
Ha= 17.05 - 16.75
[Ha= 0.305] > 0.305 THEN OK

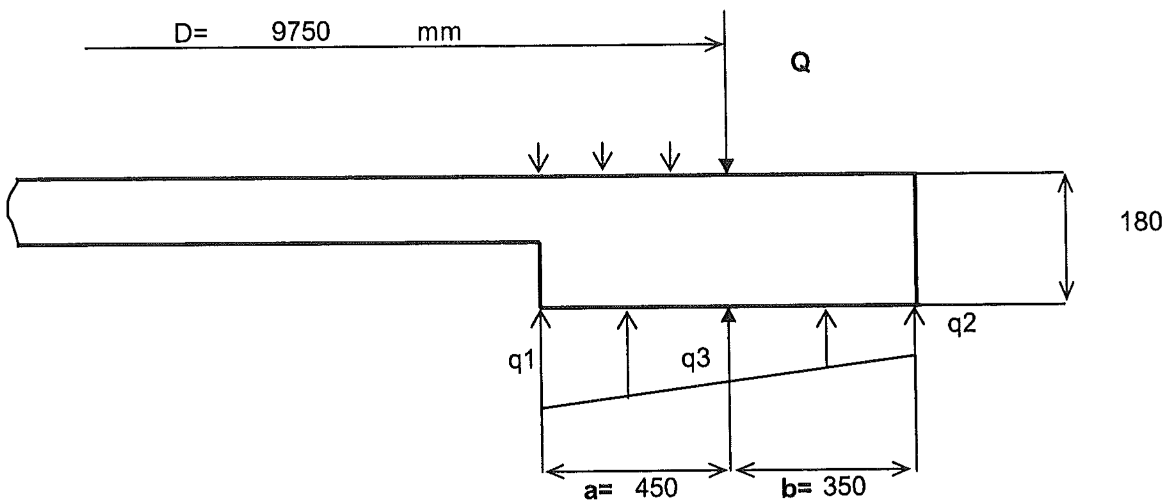
STRESSES IN CONCRETE RING AND FOAMGLAS

In the concrete ring

Load per unit of length

Q = (Wr + S) x g / Pi x D + 4 x M / pi x D²
Q = 135991 N

p = G x g x H
p = 133386 N/m²



C1 = q1 + q2
= (2 / (a + b)) x (Q + a x p)
C1 = 490038 N/m²

C2 = q1 + 2 x q2
= (6 x a / (a+ b)²) x (Q + a x p /2)
C2 = 700326 N/m²

q2 = C2 - C1
q2 = 210289 N/m²
q1 = C1 - q2
q1 = 279749 N/m²

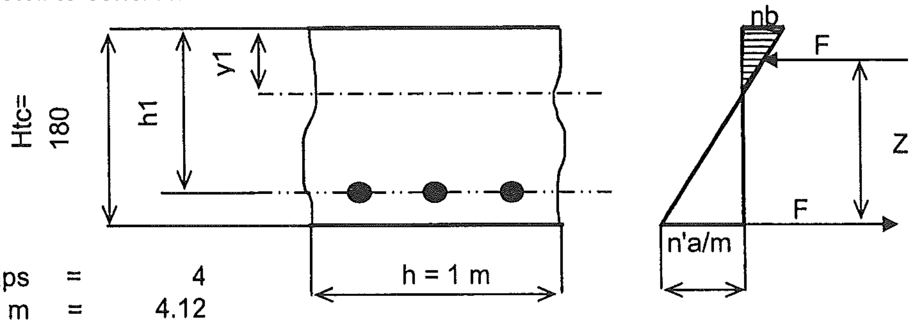
q3 = (q1 x b + q2 x a) / (a + b)
q3 = 240678 N/m²

Flexural moment in the concrete ring per unit of length

Mf = b² / 6 x (2 x q2 + q3)
Mf = 13501 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	=	4.12	
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'**	=	**827.47**	**mm²**

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

Mo = h1 / 2 x m x w'
Mo = 6.04

Nu = 1 / 2 x ((1 + 4 x Mo)$^{1/2}$) -1)
Nu = 2.008

y1 = h1 / (1 + Nu)
y1 = 0.050 m

Z = h1 - y1 / 3
Z = 0.133 m

F = M f / Z
F = 101219 N/m

n'a = F / w'
n'a = 122.32 N/mm²

nb = 2 x F / y1
nb = 4.06 N/mm²

Allowable stresses

n'a	**122.32**	**=<**	**172**	**N/mm²**	**Then OK**
nb	**4.06**	**=<**	**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 = 284164 N/m²
P = 0.28416 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= 0.2851 **MPa**

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

Calculated safety factor = 2.42 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= (38.67 + 7.64 + 7 + 48.25 + 4.99 + 2.7 + 1.)x 0.12 x 9810

Fe= 130372 N

Maximum moment at 0,00 CMP.

Me= [(38.67 x 9.37) + (7.64 x 19.74) + (7 x 19.74) + (48.25 x 9.62)
+ (2.7 x 9.37) + (1.5 x 20.74)] x 0.6 x 0.2 x 9810

Me= 1379485 Nm

8.2) Inner vessel:

Maximum horizontal shear force at 0,00 CMP.

Fb=F (page 10) = 1193552 N

Maximum moment at 0,00 CMP.

Mb = M + F x Epi

Mb = 9432625 + 1193552 x 0.97

Mb = 10592757 Nm

8.3) Isolation and concrete under the inner tank:

Maximum horizontal shear force at 0,00 CMP.
Pi = P4 + P9
Pi = 3456 + 57000 **Pi = 60456 Kg**
Fi = Pi x C1 x Z x 9.81
Fi = 60456 x 0.6 x 0.2 x 9.81
Fi = 71168 N

Maximum moment at 0,00 CMP.

Mi = Fi x Epi / 2
Mi = 71168 x 0.49
Mi = 34588 Nm

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

FT = Fb + Fi + Fe
FT = 1193552 + 71168 + 130372
FT = 1395093 N

FT = 142 t

MT = Mb + Mi + Me
MT = 10592757 + 34588 + 1379485.29
MT = 12006830 Nm

MT = 1224 tm

ANCHOR BOLTS FOR OUTER CASING :

Data :

Anchor bolt diameter :	D3 =	12.15	m	
Anchor bolt number :	n =	12		
Anchor bolt section :	s =	1040	mm²	(M42)
Allowable stress in anchor bolt :	=	165.5	MPa	
Mass of shell and stiffeners of outer casing :	m5 =	38666	kg	
Mass of roof and roof beams :	m6 =	7638	kg	
External casing diameter :	D =	12350	mm	
Outer casing internal pressure :	p =	0.001	Mpa	
Maximum bending moment at the base of the shell :	M3 =	1379485	N.m	

Uplift force per anchor bolt due to seism :

uf1 = 1 / n x 4 x M3 / D3
uf1 = 1 / 12 x 4 x 1379485.29 / 12.15

uf1 = 37846 N

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

L = p x pi x D² / 4
L = 0.001 x pi x 12350² / 4

L = 119791 N

uf2 = 1 / n x [(4 x M3 / D3) + L - (m5 + m6) x g]
uf2 = 1 / 12 x [(4 x 1379485.29 / 12.15) + 119790.89 - (38666 + 7638) x 9.81)]

uf2 = 9975 N

Tensile stress in anchor bolt :

Sp = MAX(uf1,uf2) / s
Sp = 37845.96 / 1040

Sp = 36.39 MPa < 165.50 MPa THEN OK