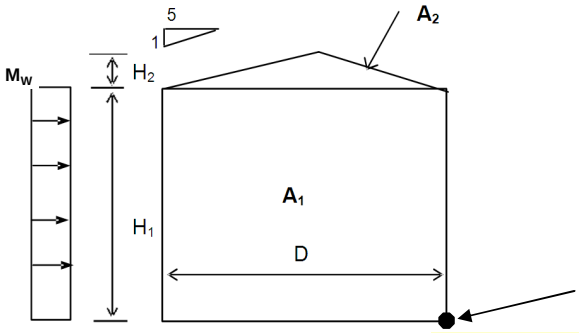
7 TANK ANCHORAGE (OVERTURNING STABILITY)

7.1 Design Code EN14015:2004, Section 12
7.2 Fluid Demineralised Water
7.3 Concept

7.3.1 Uplift due to Wind (Horizontal & Vertical)

7.3.1.1 Free Body Diagram of tank



D	=	*11*	m
H_1	=	*12.4*	m
H_2	=	*1.1*	m

7.3.1.2 Wind Pressure

Design windspeed, *V*	=	*162*	km/h
	=	*45*	m/s
Maximum windpressure, $P_{w,max}$	=	$\frac{1.48v^2}{190^2}$	
	=	*1.08*	kPa

7.3.1.3 Calculation

(a) Note:

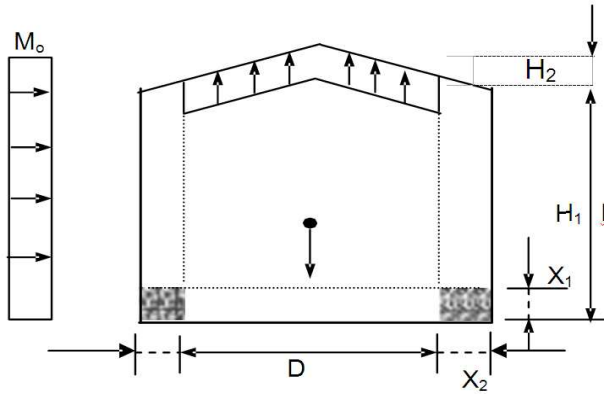
For the shell, its projected area A_1	=	H_1D	
	=	136.4	m^2
For the roof, its projected area A_2	=	$½H_2D$	
	=	6.05	m^2

(b) Overturning Moment about Shell and Bottom Joint, M_W

Moment due to wind on Shell, M_1	=	$A_1P_w(H_1/2)$	
	=	909.9	kN m
Moment due to wind on Roof, M_1	=	$A_2P_wC_d(H_1+H_2/3)$	
	=	83.1	kN m
M_W	=	$M_1 + M_2$	
	=	*993.0*	kN m

7.3.2 Uplift due to Internal Pressure

7.3.2.1 Free Body Diagram of tank



7.3.2.2 Calculation

Internal Cross Sectional Area, A_{int} = $\pi D^2/4$ m^2
= 95.0 m^2

Internal Design Pressure, P = 50 kPa

Uplift Force, F_{uplift} = 4751.7 kN

Thus, the uplift moment, M_{pi} = $\frac{1}{2}D\,F_{uplift}$
= 26134.1 kN m

7.3.3 Seismic Loading

From Annex G.2 of EN14015:2004,
The overturning moment applied to the bottom of the tank is calculated as:

$$M_{SL} = 0.009803[Z(T_t X_s + T_r H_L + T_1 X_1) + Z' T_2 X_2]$$

M_{SL} = 3949.1 kN m

..

where,

Z = *Seismic Factor (in accordance to UBC 1997)*
Z' = *Seismic Factor due to sloshing of contents and soil conditions*
T_t = *weight of tank shell, kg*
T_r = *weight of tank roof, kg*
T_1 = *effective weight of tank contents, kg*
T_2 = *effective weight of tank contents when sloshing, kg*
X_S = *height from shell bottom to centre of gravity of tank shell, m*
X_1 = *height from shell bottom to centroid of seismic force applied to T_1, m*
X_2 = *height from shell bottom to centroid of seismic force applied to T_2, m*
H_L = *height of tank shell, m*

7.3.4 Resistive Moments due to Nominal Shell and Roof Structure Supported by the Shell, M_{DL}

(excluding roof plates and structures attached to roof plates, and in corroded condition)

M_{DL} = $W_2 D/2$
M_{DL} = 1123.3 kN m

where,

W_2 = *total weight of the nominal shell and roof structures*

7.3.5 Resistive Moments due to Roof Plates and Appurtenances, M_{DLR}

(excluding roof structures supported by the shell, and in corroded condition)

M_{DLR} = $W_3 D/2$

M_{DLR} = *292.1* kN m

where,

W_3 = *total weight of the roof's plates and appurtenances*

7.3.6 Resistive Moments due to Fluid Weight

W_f = $0.1 t_a \sqrt{(F_{by} H W_s)}$, except that $w_f < 0.2 W_s$ HD

= *41.8* kN/m of shell circumference

except that W_f < *25.6* kN/m

Hence, w_f is taken as *25.6* kN/m

where,

W_f = *moment of the force that resists uplift in the annular region (kN/m)*

t_a = *annular plate thickness (mm)*

F_{by} = *min specified yield strength of bottom annulus (MPa)*

H = *height of liquid till overflow (m)*

W_s = *maximum density of liquid, not less than 1g/cm^3*

M_f = $\frac{1}{2} A_{int} w_f$

= *1215.0* kN m

7.3.7 Conclusion

M_W	=	993.0	kN m
M_{Pi}	=	26134.1	kN m
M_{SL}	=	3949.1	kN m
M_{DL}	=	1123.3	kN m
M_{DLR}	=	292.1	kN m
M_f	=	1215.0	kN m

In accordance with Clause 12.1, Unanchored Tanks shall satisfy these criteria:

(i) Uplift of an empty tank due to internal design pressure is lower than the effective weight of the corroded roof, shell and permanent attachments.
(ii) Uplift due to internal design pressure plus wind loads is lower than the effective weight of the corroded roof, shell and permanent attachments plus effective weight of products in tank
(iii) Uplift of an empty tank due to wind loads is lower than the effective weight of the corroded roof, shell and permanent attachments.
(iv) If required by Annex G (Overturning Moments due to Seismic Forces)

(i)	$M_{Pi} < M_{DL} + M_{DLR}$	=	26134.1	<	1415.4
	Safety factor	=	**0.1**		
(ii)	$M_W + M_{Pi} < M_{DL} + M_{DLR} + M_f$	=	27127.1	<	2630.4
	Safety factor	=	**0.1**		
(iii)	$M_w < M_{DL} + M_{DLR}$	=	993.0	<	1415.4
	Safety factor	=	**1.4**		
(iv)	$M_{SL} + M_{Pi} < M_{DL} + M_{DLR} + M_f$	=	30083.2	>	2630.4
	Safety factor	=	**0.1**		

Criteria are not met, therefore,
Anchor bolts are required.