NECESSARY SECTION OF INTERMEDIATE STIFFENING RINGS ON SHELL OF ABOVEGROUND STEEL TANKS

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Abstract: *Cylindrical steel tanks for oil and oil products storage are thin spatial structures. They are very sensitive to deformations in shell and lose of stability.*

According to API Std 650, BS 2654:1989 and EN 14015:2004 the thin steel shells could be stiffened using additional members known as intermediate wind girders or stiffening rings. They are circular frame elements welded to the shell.

To evaluate behavior of cylindrical shell stiffened with wind girders are created many 3D models. The sections of girders are defined according to API Std 650 or EN 14015:2004. Deflections, bending moments, axial forces in wind girders are compared and evaluated.

1. INTRODUCTION

Steel vertical cylindrical tanks have thin walls. Their shells must have a necessary thickness and strength to be assured for:

- to bear hydrostatical load by stored product and internal over pressure;
- against loss of the stability in the radial and meridian direction.

According to Bulgarian normative documents in force now in Bulgaria [1], the only one possibility to reinforce the shell against the loss of stability is by increasing the thickness of shell courses. In methodology shown in some foreign standards [3], [4], [5], the reinforcement of the shell in radial direction can be done through the mounting of the intermediate stiffening rings.

2. CREATION OF MODEL FOR STEEL VERTICAL TANK

To test the tanks behavior a lot of three dimensioned computer models have been created. Software product SAP 2000 has been used for this purpose.

Software models have been created for four standard tanks which tanks have been executed by company OKZ Holding and their volumes are respectively V=4700 m^3, V=9500 m^3, V=32500 m^3, V=46000 m^3. All models have annular bottom plates (the bottom does not have central part), shell and stiffening rings. The tanks are closed by very light fixed roof and the shell is reinforced against total loss of stability by upper supporting ring put in its upper point.

Compression forces on the shell in result of roof loads have not been reported.

The Shell elements are used for all courses and annular bottom plates. Their thickness depends on the tank course and varies $t = 6 \div 22$ mm.

For modeling of the stiffening rings Frame elements have been used which have the relevant elastic section modulus W_G for upper supporting ring and W_i for intermediate wind girders. Geometric properties for stiffening rings are determined accordingly to [3] and [5].

The used steel in the Shell and Frame elements is S235.

3. PRESSURE ON THE SHELL IN RADIAL DIRECTION

The pressure on the shell is defined according to [2]. Empty tank has been examined during the test.

a) wind pressure

$w_n = w_m.\kappa_z.c_e$ – is the normative value of the wind pressure

w_m – is the characteristic value of wind pressure on 10 m above ground level;

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It is accepted that $w_m = 1{,}235$ kN/m^2 – this is the wind pressure when the wind speed is $v = 160$ km/h.

k_z – coefficient, reporting the change of the wind speed by high;

$c_e = k_1 \,.\, c_\beta$ – streamlined coefficient for external pressure;

c_β – coefficient, when $Re > 4.10^4$ this coefficient is accepted according to the graphic on fig. 1:

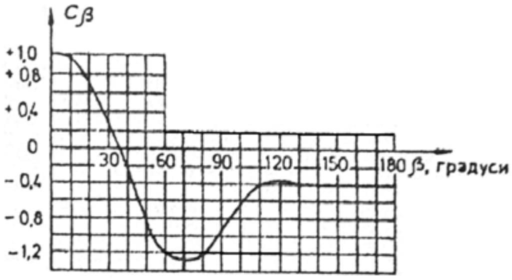


fig.1 Dependence of $\boldsymbol{c_\beta}$ from central angle **β**

When $c_\beta > 0$, coefficient $k_1 = 1{,}0$

When $c_\beta < 0$, coefficient k_1 is reported in Table 1 below, dependently on the relation between height ***H*** and diameter ***D*** of the tank.

Table 1

H/D	0,2	0,5	1	2	5	10	25
k_1 при c_β<0	0,8	0,9	0,95	1,0	1,1	1,15	1,2

$w = w_n.\gamma_w$ - design value of the wind pressure;

$\gamma_w = 1{,}4$ – coefficient of overloading by the wind pressure.

b) negative internal pressure in the tank

$p_v = p_v^n.\gamma_v$ - design value of negative internal pressure in the tank.

It is accepted $p_v^n = 0{,}5 kN/m^2$ - this is maximum value for vertical cylindrical tanks

$\gamma_v = 1{,}2$ – coefficient of overloading by negative internal pressure

4. RESULTS

The wind pressure and negative internal pressure on the tank caused the forces and deformations in its shell and the shell stiffening rings. They are shown on fig.2 – fig.7:

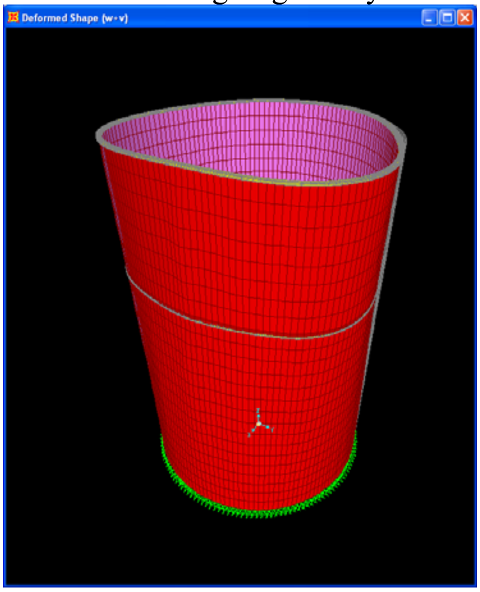


fig. 2 Shell deformation

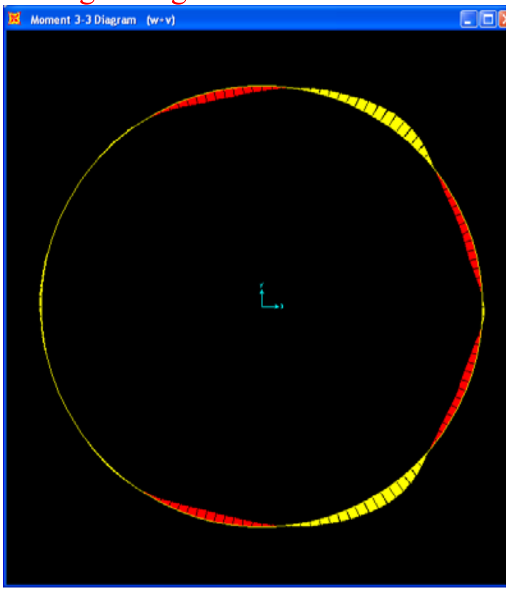


fig. 3 Bending moments in intermediate stiffening rings

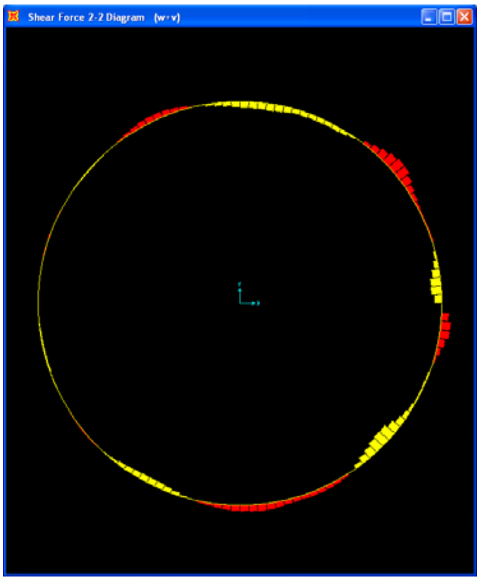
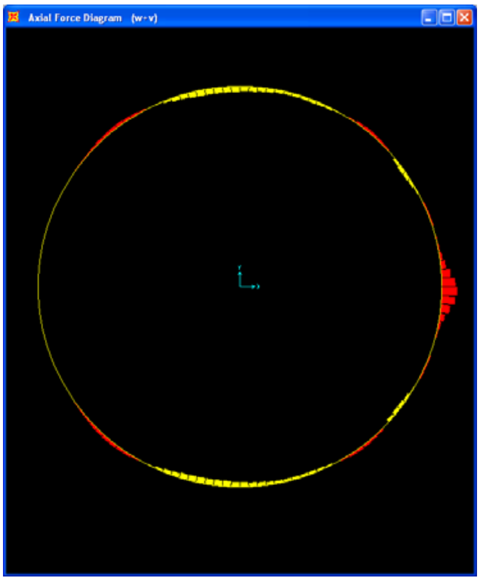
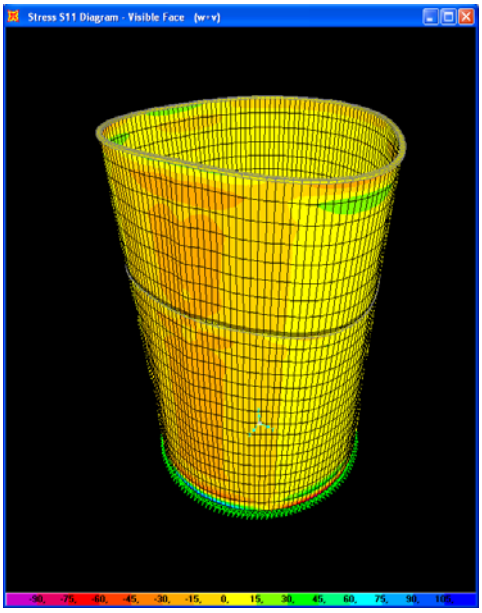


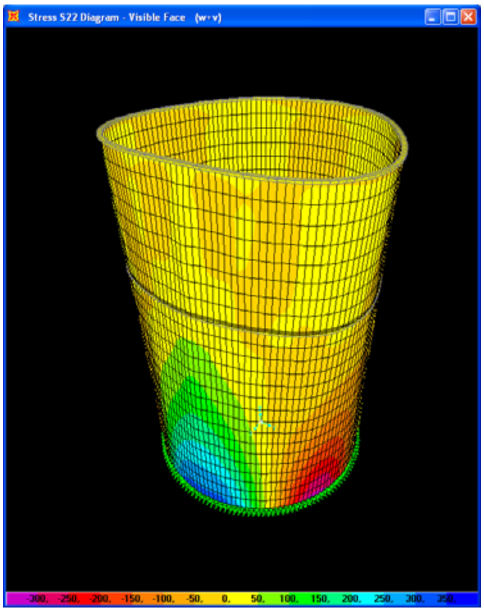
fig. 4 Shear forces in intermediate stiffening rings



фиг. 5 Axial forces in intermediate stiffening rings



фиг. 6 Stress σ_1



фиг. 7 Stress σ_2

The forces and deflections of the intermediate stiffening ring according to different normative documents are shown on Table 2 and Table 3:

Table 2 - Section on Intermediate stiffening rings defined by EN 14015

Tank	Height, m	Diameter, m	IWG	Forces, kN			Stress, kN/cm^2		Deflections, mm
				M	Q	N	σ	τ	
V=4700 m^3	24	16	L100x65x8	0,388	1,178	-12,291	1,125	0,1389	12,6
				2,593	1,893	2,776	4,22	0,2232	16,2
V=9500 m^3	14	30	L120x80x10	3,963	4,182	-53,303	5,669	0,348	1,6
				1,471	1,451	16,03	1,98	0,1209	6,4
V=32500 m^3	24	42	L150x90x10	6,14	4,416	-50,31	4,847	0,294	1,1
				1,545	0,583	11,59	1,197	0,0389	3,15
V=46000 m^3	20	55	L200x100x12	7,7	5,268	-66,17	3,87	0,263	0,12
				2,334	1,644	14,47	1,068	0,082	0,15

Table 3 - Section on Intermediate stiffening rings defined by API 650

Tank	Height, m	Diameter, m	IWG	Forces, kN			Stress, kN/cm^2		Deflections, mm
				M	Q	N	σ	τ	
V=4700 m^3	24	16	L120x80x10	0,955	0,945	-13,879	0,571	0,0788	14,3
				3,873	2,487	4,479	3,949	0,207	6,1
V=9500 m^3	14	30	L200x100x8	4,41	3,55	-58,91	3,918	0,22	2,9
				2,21	0,129	15,82	1,565	0,0081	2,4
V=32500 m^3	24	42	L250x150x10	7,099	4,746	-61,426	2,509	0,1898	3,2
				3,726	2,518	14,303	1,039	0,1	2,6
V=46000 m^3	20	55	L250x150x12,5	8,815	5,595	-77,42	2,795	0,179	0
				2,08	1,976	17,02	0,647	0,0632	1,48

5. CONCLUSION

а) bending moments ***M*** and axial forces ***N*** in the intermediate stiffening rings increase with the increase of the geometric parameters of the stiffening rings;

б) the movement of the stiffening rings in the radial direction, when the position is 0^0 toward the wind direction, increases with the increase of the geometric parameters of the stiffening rings;

в) when the geometrical parameters of the stiffening rings increase, the possibility for shell deformation decreases. It determines a smaller movement of stiffening ring when the tanks are reinforced according to [3] when the position is $\approx 40^0$ toward the wind directions;

г) tensions in stiffening rings are too small – obviously intermediate rings must be checked for loss of stability in radial direction.

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