STRESS IN JOINT BETWEEN SHELL AND BOTTOM IN STEEL TANKS WITH CATCHING BASIN

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Abstract: *Cylindrical steel tanks with double shell become to be popular in Bulgaria. They have common steel bottom for shell and catching basin. Projection of bottom outside of main reservoir is a much more than 0,05 m, as is in traditional tanks. In this case will be mistake to use methodology in standards. Results will be wrong. It is necessary to use new methods for assessment of stress in annular bottom plates.*

Key words: *cylindrical steel tank, double shell, annular bottom, stress*

1.Introduction

The stress of joint between bottom and shell in steel tanks depends on many factors one of them is projection ***C*** of the bottom out of the shell**.**

Diameter of the bottom of traditional cylindrical steel tanks is bigger than their internal shell diameter with 100 ÷ 150 mm. The double shell tanks, very popular in Germany, Czech Republic , Hungary, Poland and already constructed also in Bulgaria, have the bottom diameter which considerably exceed the internal shell diameter (fig.1). Acceptance that the projection ***C*** = 0,05 m when we determine the stress on the joint between bottom and main shell is not correct and could lead to the wrong calculations.

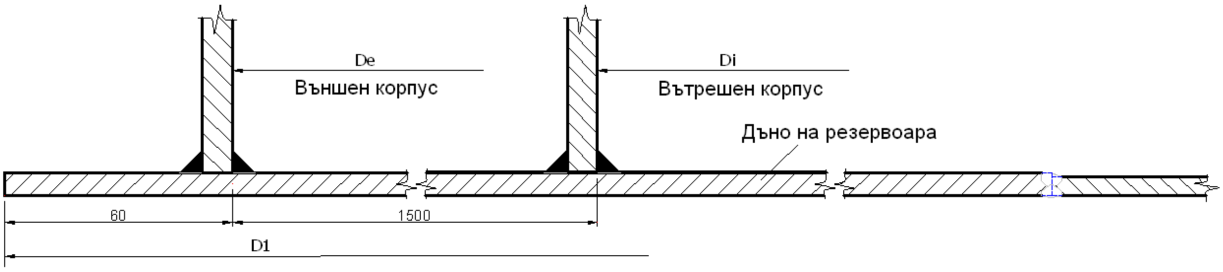

fig. 1 Detail of joint of the bottom with internal and external shells.

During the design of three tanks with double shell (fig.2), the author must check whether the accepted thickness of the first course and bottom periphery ring is sufficient. In literature available to the author is no described methodic for determining the minimal thickness of the annular bottom plates of the double shell tank. For this purpose it was necessary to create three dimensioned computer models and using them to determine the values of the real stress in the bottom joint between the internal shell and the bottom.

2.Conditions for research

The steel tanks are three types with nominal volume V=1500 m^3, V=2000 m^3 и V=3500 m^3 each one**.** They are designed for keeping petrol products with density ρ = 0,9 t/m^3 and over pressure $p_0^n = 2{,}0kPa$.

For all tanks the height of the shell ***H*** = 14,0 m and needed technological space *h* = 0,5 m. The maximal level of fill up of the tanks $\boldsymbol{H_t}$ = 0,5 m.

The shells and the bottoms are made from steel ВСт3пс5 with с yield strength $R_y^n = 225\,\text{MPa}$ and modulus of elasticity ***E*** = 2,06.10^6 MPa.

The steel bottom is entirely supported by foundation without slump and rough surface. Depending on the type of the foundation the coefficient of soil $\boldsymbol{k_b}$ varies in large scale. The author in this research accepted $\boldsymbol{k_b}$ = 20 ÷ 1000 MN/m^3 and it is valid for all foundations used in tank construction.

The efforts in the shell in axis direction caused by snow loads, wind impact on the roof, overpressure, vacuum, vary from –5 to +10 kN/m'.

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fig. 2 Steel tank with double shell and double bottom

Because bending moments in bottom and shell decrease very rapidly, projection of annular bottom plates to bottom’s center is accepted ***b*** = 600 mm. Internal shell is 2 m height. The computer model does not include the central part of the bottom because it has only constructive function of a barrier between the liquid and the soil. The outside catching basin is not included because it is positioned at a big distance from the surveyed joint between bottom and internal shell.

Fig. 3 shows frame of reference of the bottom elements.

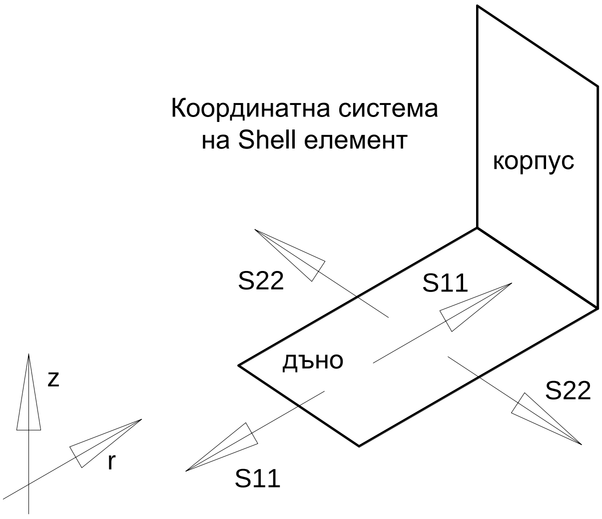

fig. 3 Coordinate system in shell elements in 3D model

3. Results from FEA research of the stress in the joint shell to bottom

3.1. Double shell tank with volume **V=1500 m^3**

3.1.1. Geometrical data for the internal shell:

Height of the shell – $\boldsymbol{H}$ = 14,0 m;

Diameter of the internal shell – $\boldsymbol{D}$ = 12,0 m;

Diameter of the bottom – $\boldsymbol{D_b}$ = 15,12 m;

Thickness of the first course in the shell – $\boldsymbol{t_{1s}}$ = 7 mm;

Thickness of the annular bottom plates – $\boldsymbol{t_{ab}} \geq 0{,}7.t_{1s}$ = 5 mm.

3.1.2. Stress in the annular bottom plates $\boldsymbol{\sigma_b}$ in the spot on its joint with the shell

TABLE 1

№	Meridional compression	Stress, MPa	Coefficient of the soil k_b, MN/m^3							
			20	50	100	200	400	600	800	1000
1	+ 5 kN/m' (compression)	s_{11}	-37,66	-27,48	-21,86	-17,01	-12,9	-10,9	-9,72	-8,91
		s_{22}	-6,69	-3,62	-1,79	-0,3	1,03	1,62	2,0	2,31
2	0,0	s_{11}	-4,4	-5,18	-5,41	-6,06	-6,51	-8,61	-8,86	-9,13
		s_{22}	-20,41	-22,84	-24,26	-26,04	-27,76	-28,97	-29,18	-29,52
3	- 5 kN/m' (tension)	s_{11}	44,81	29,76	20,75	20,75	1,0	-0,96	-1,24	-3,09
		s_{22}	-3,59	-10,67	-15,25	-15,25	-25,11	-25,16	-25,52	-25,75
4	- 10 kN/m' (tension)	s_{11}	40,95	29,73	22,5	22,5	9,97	6,4	4,16	1,97
		s_{22}	-26,23	-20,72	-20,03	-20,03	-21,82	-22,82	-23,57	-24,07

3.2. Tank with double shell and volume **V=2000 m^3**

3.2.1. Geometrical data for the inside shell:

Height of the shell – $\boldsymbol{H}$ = 14,0 m;

Diameter of the inside shell – $\boldsymbol{D}$ = 13,9 m;

Diameter of the bottom – $\boldsymbol{D_b}$ = 17,02 m;

Thickness of the first course in the shell – $\boldsymbol{t_{1s}}$ = 9 mm;

Thickness of the annular bottom plates – $\boldsymbol{t_{ab}} \geq 0{,}7.t_{1s}$ = 7 mm.

3.2.2. Stress in the annular bottom plates $\boldsymbol{\sigma_b}$ in the spot on its joint with the shell

TABLE 2

№	Meridional compression	Stress, MPa	Coefficient of the soil k_b, MN/m^3							
			20	50	100	200	400	600	800	1000
1	+ 5 kN/m' (compression)	s_{11}	-10,87	-11,64	-13,28	-14,38	-15,39	-15,54	-15,59	-15,03
		s_{22}	1,32	-10,67	-17,06	-20,61	-21,88	-20,87	-19,6	-17,31
2	0,0	s_{11}	3,66	-1,46	-6,4	-10,27	-13,48	-14,37	-14,12	-13,86
		s_{22}	5,38	-8,21	-15,34	-19,32	-21,04	-20,01	-19,36	-17,82
3	- 5 kN/m' (tension)	s_{11}	18,44	8,82	-1,97	-6,23	-10,75	-12,69	-13,11	-13,12
		s_{22}	9,07	-5,48	-13,48	-18,21	-20,71	-20,09	-19,08	-17,67
4	- 10 kN/m' (tension)	s_{11}	32,72	18,27	7,66	-8,24	-8,24	-11,01	-11,21	-11,4
		s_{22}	13,08	-3,05	-11,76	-20,01	-20,01	-19,06	-18,57	-16,46

3.3. Tank with double shell and volume **V=3500 m^3**

3.3.1. Geometrical data for the inside shell:

Height of the shell – $\boldsymbol{H}$ = 14,0 m;

Diameter of the inside shell – $\boldsymbol{D}$ = 18,0 m;

Diameter of the bottom – $\boldsymbol{D_b}$ = 21,12 m;

Thickness of the first course in the shell – $\boldsymbol{t_{1s}}$ = 11 mm;

Thickness of the annular bottom plates – $\boldsymbol{t_{ab}} \geq 0{,}7.t_{1s}$ = 9 mm.

3.3.2. Stress in the annular bottom plates $\boldsymbol{\sigma_b}$ in the spot on its joint with the shell

TABLE 3

№	Meridional compression	Stress, MPa	Coefficient of the soil k_b, MN/m^3							
			20	50	100	200	400	600	800	1000
1	+ 5 kN/m' (compression)	s_{11}	-41,96	-17,6	-6,07	1,53	-0,96	9,02	10,26	10,86
		s_{22}	15,91	26,06	32,08	36,6	34,3	40,51	40,63	40,64
2	0,0	s_{11}	-25,25	-6,53	4,49	9,94	13,36	14,64	15,86	12,92
		s_{22}	20	28,54	33,94	37,82	40,34	41,1	41,21	41,57
3	- 5 kN/m' (tension)	s_{11}	-16,84	-1,02	6,9	12,25	15,57	16,77	17,73	18,01
		s_{22}	23,55	32,1	37,07	40,42	42,58	43,18	43,18	43,11
4	- 10 kN/m' (tension)	s_{11}	-3,42	12,65	18,44	22,14	23,72	24,18	24,2	24,41
		s_{22}	27,77	36,78	41,04	43,94	45,63	45,8	45,73	45,43

4. Stress calculation according to classical method for a tank with V=3500 m^3 capacity

In order to compare the results obtained through FEA methods, the calculations for determination of stress in the annular bottom plates have been done with traditional methodology. The research conditions are identical. The unique difference is that in the traditional method projection of the bottom outside of the shell ***C*** = 0,05 m.

Stress in annular bottom plates are determined according to traditional methodology to make comparison of results determined with FEA. Conditions of research are identical. Only difference is that in traditional methodology projection of annular bottom plates outside of shell is ***C*** = 0,05 m.

The stress variation in the annular bottom plates $\boldsymbol{\sigma_b}$ in the spot of joint between shell and bottom depending on coefficient of the bed $\boldsymbol{k_b}$ is shown on fig. 4 ÷ fig. 7.

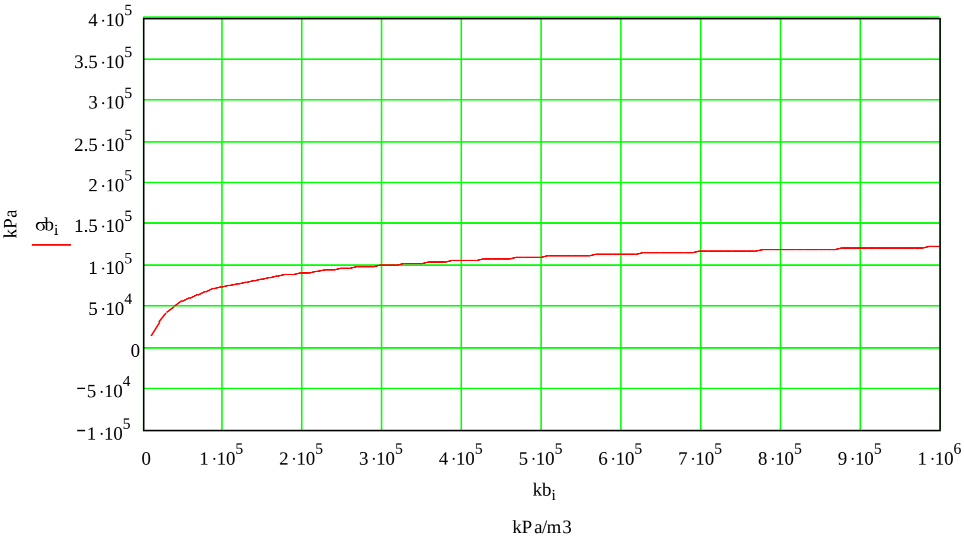

fig. 4 The stress variation in the annular bottom plates $\boldsymbol{\sigma_b}$ in the spot of joint between shell and bottom by meridional compression +5 kN/m' (compression)

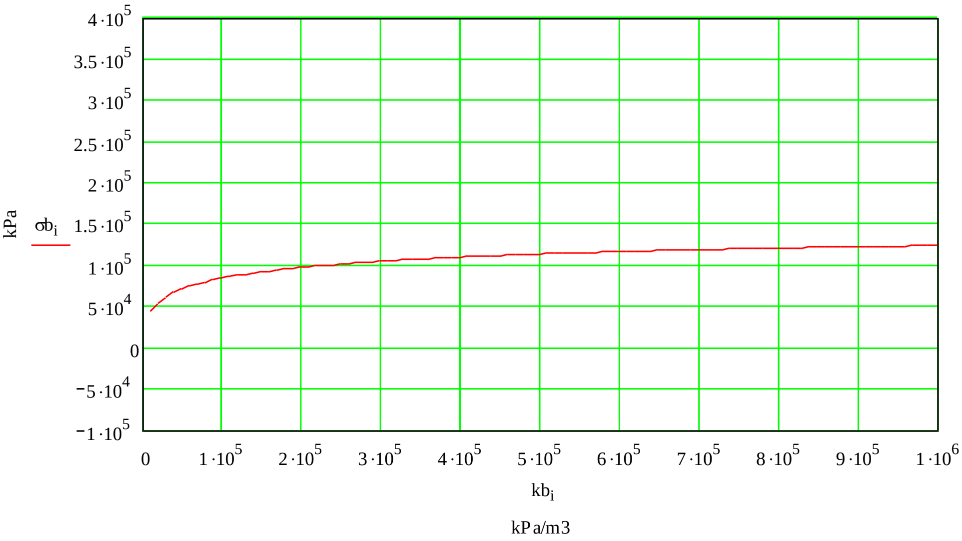

fig. 5 The stress variation in the annular bottom plates $\boldsymbol{\sigma_b}$ in the spot of joint between shell and bottom by meridional compression in joint 0,00 kN/m'

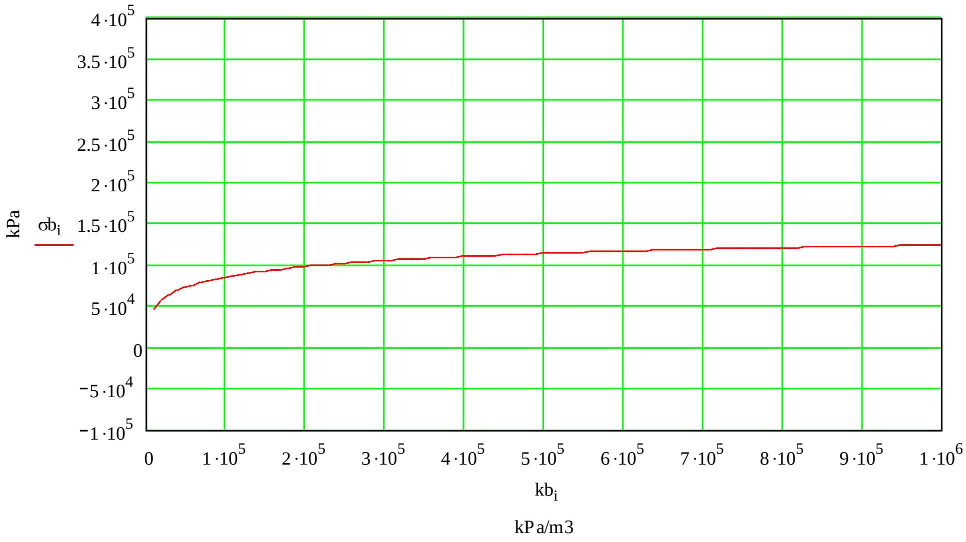

fig. 6 The stress variation in the annular bottom plates $\boldsymbol{\sigma_b}$ in the spot of joint between shell and bottom by meridional compression in joint -5 kN/m' (tension)

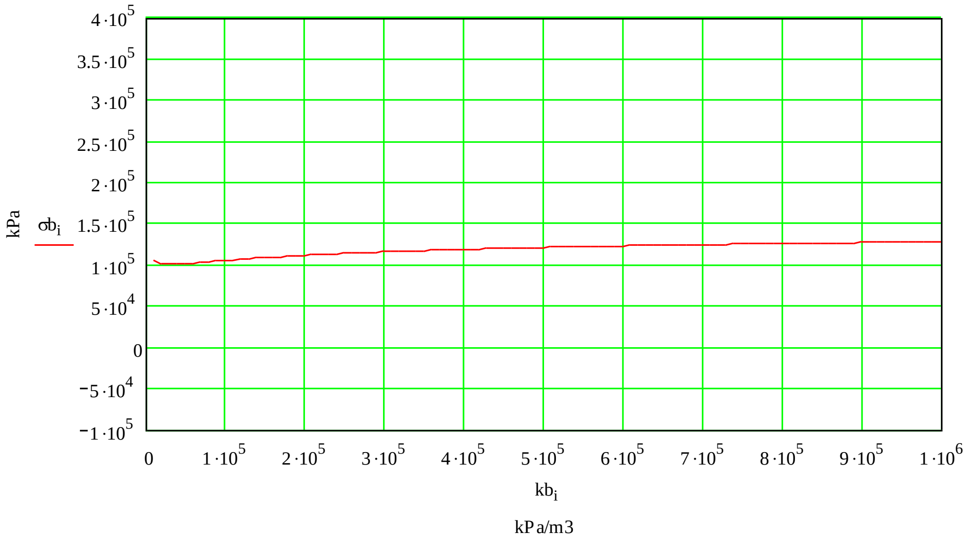

fig. 7 The stress variation in the annular bottom plates $\boldsymbol{\sigma_b}$ in the spot of joint between shell and bottom by meridional compression in joint -10 kN/m' (tension)

4.Conclusions

- when the thickness of the shell and annular bottom plates are in relation ($t_{ab} \geq 0{,}7.t_{1s}$), the caused bottom stress are small and far below from the yield strength $R_y^n = 225\,\mathrm{MPa}$;

-when it is possible radial movement of the bottom the stress in ring direction are often bigger than the stress in radial direction ;

- when the values of coefficient k_b of soil increase, absolute value of the rings stress s_{22} also increases.