MECHANIKA
TEORETYCZNA
I STOSOWANA
2/3, 21 (1983)

ANALYSIS OF THE STRESS STATE IN THE CYLINDRICAL SHELLS OF THE CONCRETE TANKS PRESTRESSED BY EXTERNAL TENDONS

ANDRZEJ SERUGA

Kraków

1. Introduction

The state of stress in cylindrical shells of the prestressed concrete tanks depends mailny on:

— the constructional and technological realization of the tank wall,
— the method of joining the wall and the tank bottom,
— the adapted method of prestressing of the cylindrical shell.

The knowledge of the intensity degree of the effect of the above mentioned agents on the statical work of the shell is very important in the process of the tank construction design. An especially essential problem is the determination of the amount of prestressing tendons (wires) as well as the arrangement thereof along the tank wall height. In the practice, hitherto this task was being solved by means of the determination of the envelope curve of the circumferential forces exerted by the pressure of a liquid under assumption that a determined value of friction coefficient in the joint of wall and the tank bottom exists. The analysis of stress state within the cylindrical shell is then reduced only to checking the circumferential stresses within the concrete for a prestressed tank, which in loaded by the liquid pressure, assuming that the load distribution due to the prestressing is of the sectional uniform type.

Moreover the resistance of concrete against the stress cracks for the maximum vertical bending moment results from the thrust of liquid or ground. However, the state of stress produced by the total or partial prestressing of the tank wall is not analysed. Such a method of design causes the following restrictions:

— the distribution of loads arising from the prestressing force is in fact a discontinuous one, thus an overloading of the shell may occur during prestressing,
— the effect of the prestressing technology on the distribution of the internal forces within the shell is not taken into account. It should be emphasized in this connection that the maximum vertical bending moments must not indispensably be originated, after the prestression of all circumferential tendons has been completed.

Many cracks in cylindrical shells of concrete tanks during prestressing were observed in the practice. Such phenomena make it necessary to carry out an exact analysis of the effect of prestressing on the distribution of internal forces within the tank wall.

During the recent 15 years in the Institute of Materials and Building Structures, Technical University of Cracow, very intensive investigation works have been carrying out to explain and determine the range of influence of the agents mentioned above on the behaviour of the tank wall during prestressing as well as during its exploitation. The results of the above works can be found in papers [1, 2, 3, 4] in which the necessity of carrying out the proper analysis of stress state in the cylindrical shell of the tank was proved, assuming the load resulting from the prestressing consists of circular — symmetrical concentrated forces.

In the present paper the estimation of one of the most used constructional realizations was made, based on an example of a tank with a capacity of 5000 cu m.

2. Experimental investigations

2.1. Description of the construction. The constructional realization of the tank was to some extent reduced because of the necessity to adapt an existing tank for drinking water.

The design thickness for the floor slab was 0.40 m. The tank wall, with a height of $H = 5.6$ m, the internal radius being $R_i = 17.5$ m and the thickness being $t = 0.18$ m, was made in monolithic system: the concrete works being executed in subsequent sections and the circumference was divided into 8 fields and 8 pilasters. The individual segments of the wall were poured with the concrete using the platform — and — the movable formwork during one day cycle. The top of the wall between the pilasters was made thicker to execute — during the next stage of work — a roof ring beam of reinforced concrete. The pilasters of the dimensions $5.6 \times 1.2 \times 0.38$ m each were symmetrically arranged on the tank wall circumference.

The connection of the bottom slab with the cylindrical shell was executed as a sliding joint, the friction coefficient being assumed in statical calculations to be $\mu = 0.3$. The tank wall was set on the bottom of the groove of foundation ring, the depth being 0.2 m, using the slide layer made of two layers of bitumen board with glue. The internal chase of foundation ring was filled with tallow cord and Abizol KF putty first to prestressing the tank wall.

The prestressing of the tank wall was executed using double-bay external tendons of Freyssinet type 18 Ø 5 mm, running on the rolling pad of 12 mm dia.

2.2. Characteristic of the building materials used

Concrete

During pouring the concrete in the tank wall formwork, the test specimens of 15×30 cm cylinder were sampled to determine the compressive strength as well as the modulus of elasticity of the concrete just in the moment of prestressing the tank wall. The mean compressive strength of concrete determined using 62 specimens is equal to 37.8 MPa, the standard deviation being $s = 6.16$ MPa, whereas coefficient of variation was equal to $\nu = 16.31\%$ which would mean, that a concrete of B 35 class was obtained. The modulus of elasticity in compression was determined using 31 specimens, the full cycle of load being assumed. The obtained values are listed below.

$$\bar{E}_{0.2} = 28080 \text{ MPa}; \; s = 2339 \text{ MPa}; \; \nu = 8.33\%$$
$$\bar{E}_{0.3} = 27400 \text{ MPa}; \; s = 2220 \text{ MPa}; \; \nu = 8.10\%$$
$$\bar{E}_{0.4} = 26630 \text{ MPa}; \; s = 2044 \text{ MPa}; \; \nu = 7.67\%$$
$$\bar{E}_{0.5} = 25760 \text{ MPa}; \; s = 2257 \text{ MPa}; \; \nu = 8.76\%$$
$$\bar{E}_{0.6} = 24500 \text{ MPa}; \; s = 2410 \text{ MPa}; \; \nu = 9.84\%$$

The results in question refer to a concrete made of a granite aggregate, whereas the first two segments of walls between the pilasters No 3 and No 4 as well as No $4 \div 5$, respectively were accomplished by use of basalt aggregate. The mean compressive strength of the concrete determined in analogous manner, is equal to 55.1 MPa which means, that the concrete is of B 45 class. The modulus of elasticity in compression is $E_c = 36000$ MPa.

Prestressing steel.

Basing on the executed laboratory investigations the following mechanical properties of steel with 5 mm dia. were determined:

— the characteristic strength of steel,
— the proof stress $R_{e0.2}$,
— the modulus of elasticity
— the elongation of steel at rupture,
— the number of contraflexures

The strength of steel was determined using 38 samples taken at random, by means of multipurpose testing machine of ZD-50 type, the measurement accuracy being 250 N. The obtained main value, the standard deviation as well as the coefficient of variation are respectively equal to:

$$\bar{R} = 1721.7 \text{ MPa}; \quad s = 69{,}4 \text{ MPa}; \quad \nu = 4.03\%$$

The strength characteristic of prestressing steel is

$$R_{vk} = \bar{R} - 1.64 \cdot s = 1607.9 \text{ MPa}$$

whereas the calculated strength is equal to

$$R_v = \frac{1}{1.25} \cdot R_{vk} = 1286.3 \text{ MPa}$$

The proof stress $R_{e0.2}$ determined using 10 samples is 1478.3 MPa.

The modulus of elasticity of the prestressing steel was determined on the level of loads equal to $0.4 \div 0.6$ of the tensile breaking stress. The adapted level of load $(14 \div 20)$ kN corresponds approximately to the value $0.5\ R_{vk}$, which is below the admissible stress after immediate and rheological losses. The obtained results are as follows:

$$\bar{E}_v = 202625 \text{ MPa}; \; s = 3069.5 \text{ MPa}; \; \nu = 1.51\%$$

Elongation at rupture $A_{100} = 5.7\%$
Alternate bend test $\bar{n} = 5.35$

2.3. Program and methodology of the investigations. To estimate the stati work of the shell the following investigations were considered to be necessary:

— measurement of the radial displacements of the tank wall at the level of its connection with the foundation ring,
— measurement of the radial displacements of the tank wall along the vertical section,
— measurement of the tank circumference shortening, i.e. the diminishing of the circumference exerted by the elimination of distances between the pilasters and tank wall segments coming mutually to contact due to the prestressing,
— measurement of the strains of the tank wall concrete in circumferential and vertical directions.

2.3.1 Measurement of the radial displacements of the tank wall at the level of its connection with the foundation ring. The experimental investigations were carried out for the connection sealed with the tallow cord, 50 × 50 mm, tamped therein, which then was covered with the Abizol KF type putty. The measurements were carried out using 60 dial gauges, the range being 0.01 m and the measurement accuracy being 0.01 mm, stabilised in foundation ring at the height of 0.25 m. The arrangement of measuring points is shown in Fig. 1.

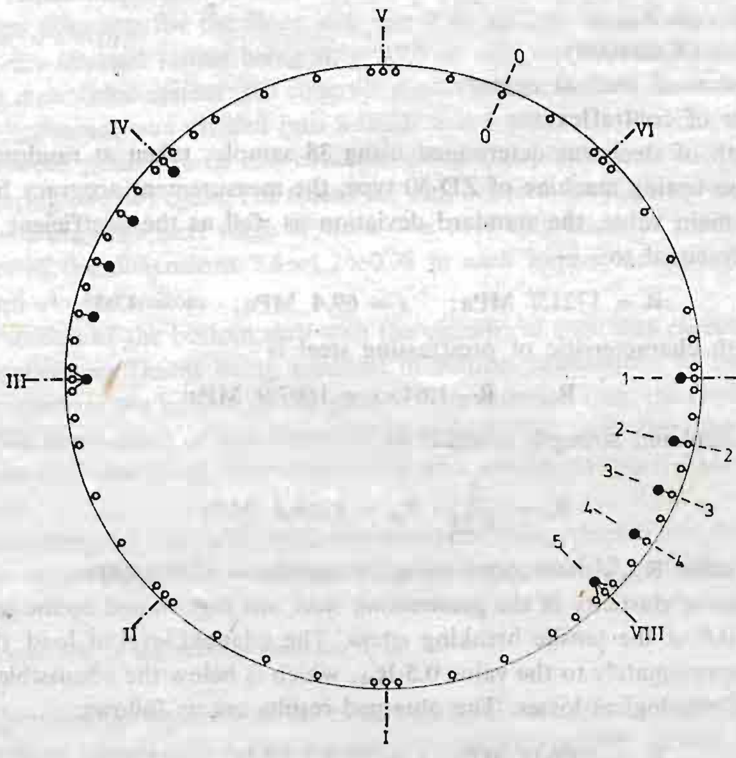

Fig. 1

2.3.2. Measurement of the radial displacements of tank wall along the vertical section. The values of the tank wall deflections were measured using dial gauges placed at the following heights: 0.25, 0.6, 1.2, 1.8, 2.4, 3.0, 3.6, 4.2, 4.8, 5.2 and 5.6 m within ten sections, on two opposite fields of the tank. The arrangement of the measuring points was made possible owing to a steel construction, made especially for this purpose, which could be connected with the floor slab in stable manner. The localization of the measuring positions is shown in Fig. 1.

2.3.3. Measurement of the tank circumference shortening. According to the adapted technology of tank wall execution there were 16 vertical work contacts. By use of the installed dial gauges the total values of radial displacements were measured. The author decided to measure additionally the tank circumference shortening and to reduce properly the displacement values. The shortening of the circumference was determined by means of DEMEC strain-gauge measurement base of which was 12 inch. The measuring points were placed at the following heights: 0.25, 0.65, 1.05, 1.45, 1.85, 2.25, 2.65, 3.05, 3.45, 3.85, 4.25, 4.65, 5.05, and 5.55 m.

2.3.4. Measurement of the strains of the tank wall concrete in circumferential and vertical directions. During the prestressing the concrete strains were determined by means of a standard DEMEC 8 inch straingauge. The measuring points were placed on the inside face of the tank wall in six vertical sections.

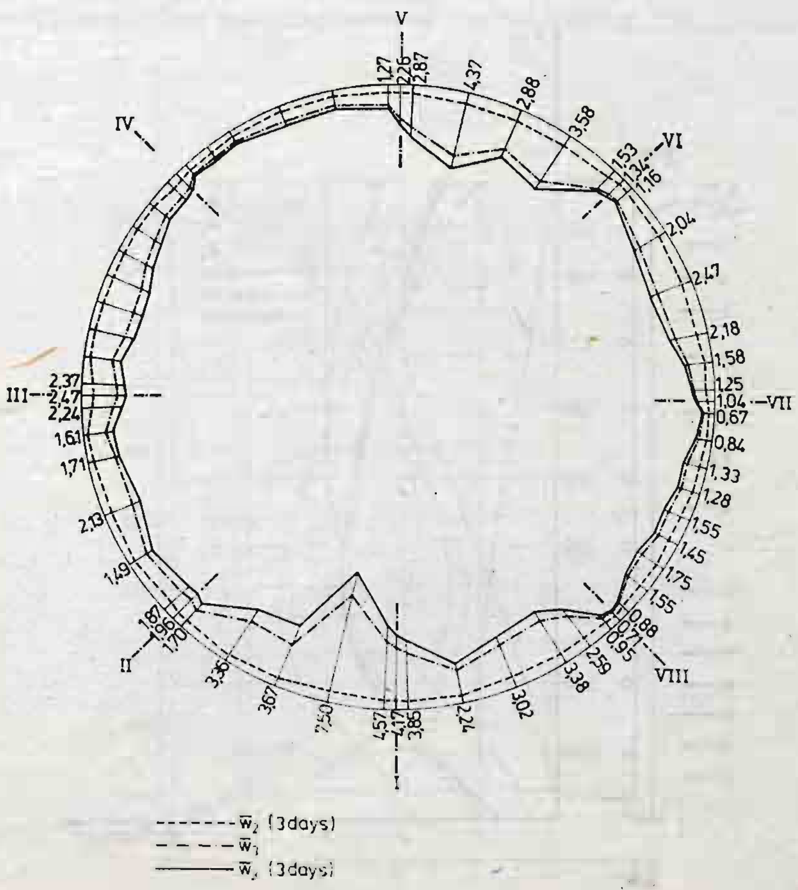

Fig. 2

The arrangement of the individual sections: 0-0, 1-1, 2-2, 3-3, 4-4 and 5-5, respectively is shown in Fig. 1. Additionally in the section 3-3 the measuring points on the outside face of the tank wall were placed between the prestressing tendons.

2.4. Results of the investigations. All readings of the displacements as well as of the concrete strains were carried out at the morning before the sunrise at a constant temperature: the prestressing of tank wall was executed during a fortnight.

2.4.1. The radial displacements of the tank wall at the level of 0.25 m. The prestressing of the tank wall was executed according to the sequence shown in Fig. 3, starting at the upper edge of shell. The measurements of the displacements were carried out as a rule in three stages, i.e. after 5, 10 and 15 tendon circumferences have been prestressed. The distribution of displacement values for the 2-nd and 3-rd stage is shown in Fig. 2. The displacements of the second stage, as well as the final ones of the third stage were read after a 3-days period of stabilization elapsed, whereas the initial displacements of the third stage were measured the next day after the prestressing completion. The mean values of displacements and the

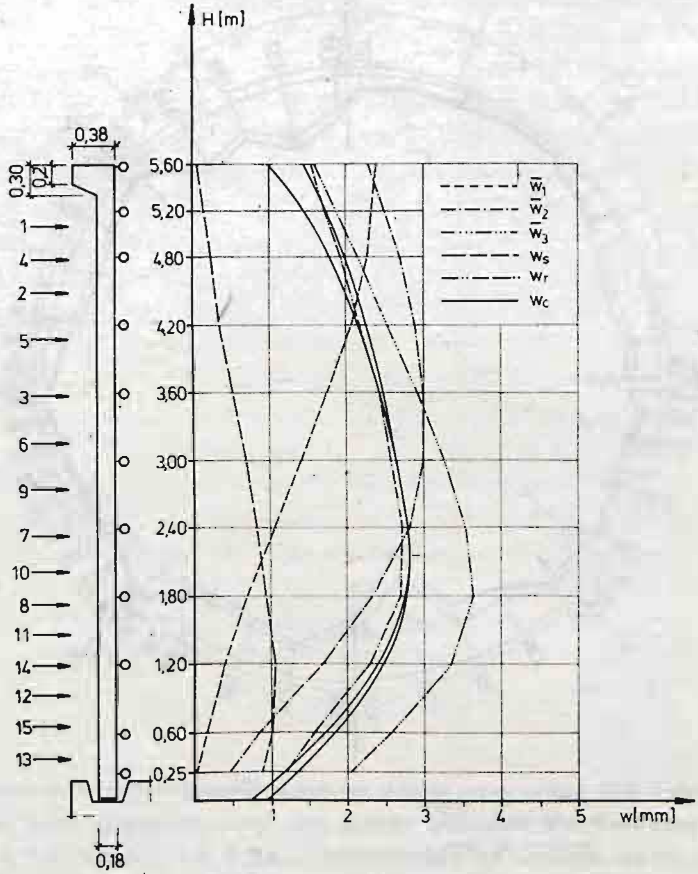

Fig. 3

distribution parameters corresponding with them are respectively:

$\bar{w}_1 = 0.0467$ mm, $s = 0.0632$ mm, $v = 135.3\%$
$\bar{w}_2 = 0.4217$ mm, $s = 0.1212$ mm, $v = 28.75\%$ (3 days)
$\bar{w}_3 = 1.7333$ mm, $s = 0.9809$ mm, $v = 56.59\%$
$\bar{w}_3 = 2.0833$ mm, $s = 1.1873$ mm, $v = 56.99\%$ (3 days)

2.4.2. The radial displacements of the tank wall along the vertical section. As the cracks were originated in the tank wall at the final stage of prestressing, e.g. on the circumference part between the pilasters No 7 and No 8, the measured displacement values were worked up in separate manner for opposite measurement positions. The obtained mean values of displacements for individual loading stages are listed in Table 1. Moreover, this table contains also the values of radial displacements corresponding with the measured shortening of the tank wall circumference as well as the reduced values of displacements for total prestressing of the cylindrical shell. The distribution of the mean values of displacements along the height of the tank wall is shown in Fig. 3 and Fig. 4 respectively.

2.4.3. Strains of the tank wall concrete. The measurements of concrete strains were carried out two times, i.e. firstly at the beginning of the prestressing and then after a three — days period of stabilization, since the completion of the prestressing. The obtained results

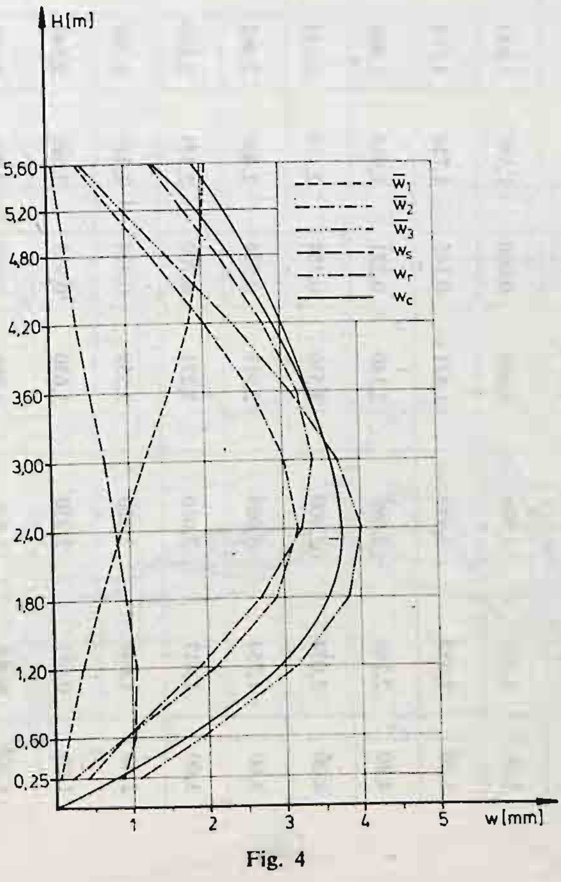

Fig. 4

Table 1. Radial displacements of the concrete tank wall w [mm]

Height of the tank wall H [m]	Concrete tank wall between pilasters No 3÷No 4						Concrete tank wall between pilasters No 7÷No 8					
	Number of tensioning tendons			w_s	$w_r = \bar{w}_3 - w_s$	w_c	Number of tensioning tendons			w_s	$w_r = \bar{w}_3 - w_s$	w_c
	$\bar{w}_1$ Stage I 5×4	$\bar{w}_2$ Stage II 10×4	$\bar{w}_3$ Stage III 15×4				$\bar{w}_1$ Stage I 5×4	$\bar{w}_2$ Stage II 10×4	$\bar{w}_3$ Stage III 15×4			
5,60	2,397	2,300	1,606	0,060	1,546	1,443	2,051	1,324	0,424	0,060	0,364	1,915
5,20	2,333	2,493	1,871	0,145	1,726	1,713	2,017	1,759	0,986	0,145	0,841	2,291
4,80	2,289	2,696	2,140	0,221	1,919	1,959	1,974	2,204	1,553	0,221	1,332	2,636
4,20	2,074	2,900	2,530	0,354	2,176	2,244	1,823	2,769	2,389	0,354	2,035	3,039
3,60	1,754	3,009	2,917	0,514	2,403	2,462	1,556	3,196	3,137	0,514	2,623	3,348
3,00	1,417	3,010	3,271	0,700	2,571	2,650	1,213	3,400	3,726	0,700	3,026	3,602
2,40	1,049	2,820	3,559	0,824	2,735	2,780	0,900	3,249	4,030	0,824	3,206	3,741
1,80	0,691	2,350	3,650	0,953	2,697	2,749	0,619	2,711	3,867	0,953	2,914	3,601
1,20	0,401	1,681	3,366	1,072	2,294	2,420	0,376	1,869	3,163	1,072	2,091	2,962
0,60	0,163	0,856	2,583	1,028	1,555	1,727	0,170	0,913	1,936	1,028	0,908	1,715
0,25	0,039	0,461	2,051	0,892	1,159	1,180	0,066	0,427	1,109	0,892	0,217	0,748
0,00						0,757						0,000

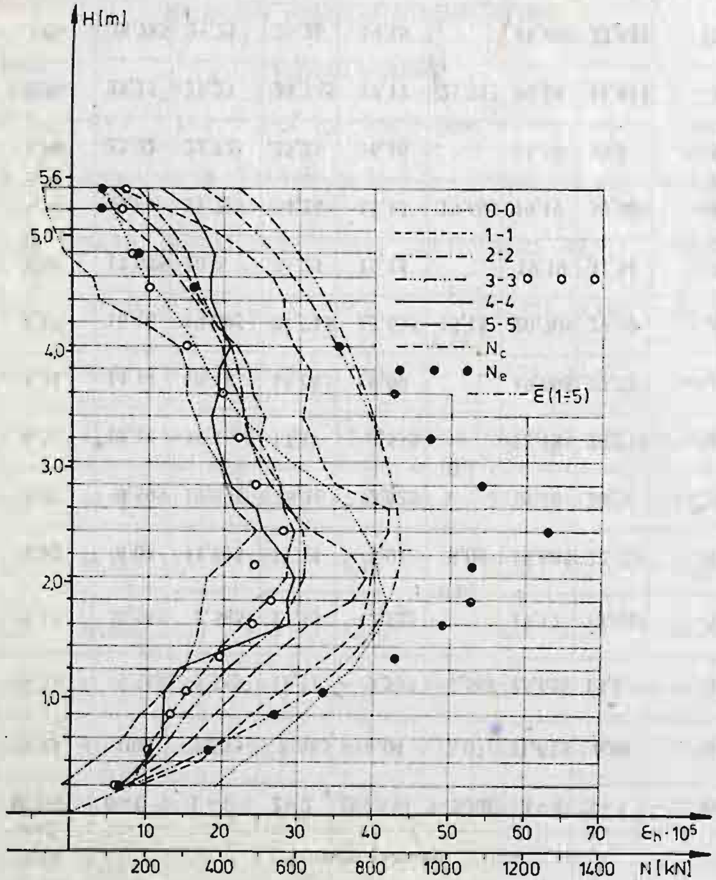
H[m]
5,6
5,0
4,0
3,0
2,0
1,0
10
20
30
40
50
60
70
$\varepsilon_h \cdot 10^5$
200
400
600
800
1000
1200
1400
N[kN]
0-0
1-1
2-2
3-3
4-4
5-5
N_c
N_e
$\bar{\varepsilon}$(1:5)

Fig. 5

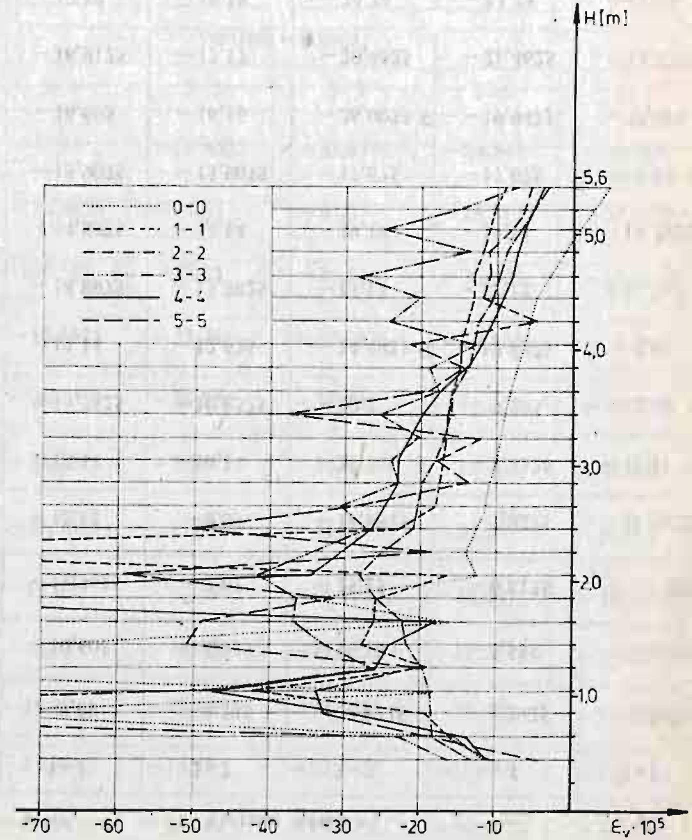
H[m]
5,6
5,0
4,0
3,0
2,0
1,0
-70
-60
-50
-40
-30
-20
-10
$\varepsilon_v \cdot 10^5$
0-0
1-1
2-2
3-3
4-4
5-5

Fig. 6

Table 2. Strains of the concrete tank wall

Height of the tank wall H [m]	Horizontal strains of concrete $\varepsilon_h \cdot 10^5$							Veritcal strains of concrete $\varepsilon_v \cdot 10^5$					
	Vertical sections							Vertical sections					
	0 - 0	1 - 1	2 - 2	3 - 3 in	3 - 3out	4 - 4	5 - 5	0 - 0	1 - 1	2 - 2	3 - 3	4 - 4	5 - 5
5,53	4,04	3,535	8,585	−4,04	7,07	11,615	6,06	4,2925	−9,09	−3,535	−7,8275	−4,2925	−5,8075
5,33	5,555	5,555	11,11	−3,535	6,565	15,655	13,13	3,535	−10,605	−5,555	−16,16	−5,555	−6,8175
5,12	6,565	8,585	13,13	−2,525		17,17	18,685	0,505	−11,3625	−7,07	−25,25 c	−6,8175	−8,3325
4,92	8,08	11,615	15,15	−1,01	8,08	18,685	22,725	−1,2625	−12,12	−9,09	−13,8875	−7,8275	−11,3625
4,72	9,595	13,635	16,16	2,525	10,1	18,18	26,26	−3,2825	−13,13	−10,1	−28,785 c	−8,3325	−11,11
4,51	12,12	16,16	17,17	3,535		18,18	27,775	−5,05	−13,3825	−10,8575	−20,2 c	−9,595	−12,12
4,31	14,14	18,18	18,685	9,09		19,695	27,775	−5,8075	−14,14	−12,625	−24,4925 c	−10,8575	−5,05
4,11	16,16	19,695	21,715	13,635	15,15	20,705	29,29	−6,8175	−14,8975	−13,3825	−13,13	−12,12	−21,715 c
3,91	17,675	20,2	23,23	15,15		19,19	31,31	−7,575	−14,8975	−14,14	−19,19	−14,14	−14,3925
3,70	19,695	21,715	24,24	15,15	19,695	19,19	30,805	−8,585	−15,9075	−15,9075	−17,675	−17,675	−19,19
3,50	22,22	22,725	25,25	16,16		18,18	30,3	−9,3425	−16,665	−16,16	−26,0075 c	−19,9475	−37,875 c
3,30	25,25	23,23	24,745	17,17	21,715	19,19	31,815	−9,8475	−16,9175	−17,17	−20,4525	−21,4625	−12,3725
3,09	28,785	25,25	26,26	19,19		19,695	32,825	−10,3525	−17,17	−18,18	−24,24	−23,23	−18,18
2,89	33,33	27,27	27,27	20,2	24,24	20,705	34,845	−11,3625	−17,675	−19,9475	−23,23	−23,23	−13,8875

Height of the tank wall H [m]	Horizontal strains of concrete $\varepsilon_h \cdot 10^5$							Vertical strains of concrete $\varepsilon_v \cdot 10^5$					
	Vertical sections							Vertical sections					
	0 - 0	1 - 1	2 - 2	3 - 3 in	3-3out	4 - 4	5 - 5	0 - 0	1 - 1	2 - 2	3 - 3	4 - 4	5 - 5
2,69	36,36	28,28	27,775	21,21		24,24	41,915	−11,8675	−18,18	−20,4525	−31,0575 C	−24,745	−28,785
2,48	38,38	31,815	29,29	24,24	27,775	25,25	41,915	−12,8775	−23,4825	−21,21	−27,27	−26,5125	−51,2575 C
2,28	39,895	36,865	28,28	21,21	24,24	27,775	39,895	−14,14	−109,585 C	−25,25 C	−34,845	−30,805	−18,4325
2,08	40,4	38,885	28,28	17,675		29,29	39,39	−12,625	−16,4125	−28,785 C	−42,1675 C	−34,5925	−59,59 C
1,87	41,41	36,865	25,755	17,17	26,26	28,28	38,885	−34,5925 C	−26,0075	−26,26	−36,36 C	−111,605 C	−31,5625
1,67	40,905	31,31	22,725	16,665	23,735	28,785	38,38	−16,25	−26,26	−22,4725	−36,865	−13,13	−48,985 C
1,47	38,885	27,775	19,695	16,16	19,695	21,21	35,35	−74,235 C	−28,0275	−21,9675	−33,0775	−24,24	−51,005 C
1,26	36,865	24,24	17,675	15,15		14,14	31,31	−126,5025 C	−19,695	−19,695	−26,5125	−26,0075	−19,4425
1,06	33,33	21,715	15,15	12,12	15,15	12,12	27,27	−18,4325	−42,42 C	−18,685	−47,7225 C	−48,2275 C	−34,0875 C
0,86	30,3	18,685	13,13	9,09	13.13	12,12	23,735	−83,0725 C	−19,19	−18,9375	−137,6125 C	−28,785	−32,825 C
0,65	26,765	16,16	11,11	7,07	10,1	12,12	20,2	−15,4025	−15,9075	−18,18	−22,4725	−13,635	−17,17
0,45	22,725	12,625	9,595	3,03		10,1	17,17	−10,8575	−10,605	−13,13	−15,9075	−10,8575	−3,7875
0,25	19,19	7,575	7,575	−1,01	6,06	7,07	9,595						

C — cracking of the concrete tank wall of concrete strains in circumferential and vertical direction are listed in Table 2, whereas the distribution of strains along the height of the tank wall are shown in Fig. 5 and Fig. 6, respectively. The concrete strains on the outside face of the tank wall according to the section 3-3 were measured only in circumferential direction, as there occured difficulties resulting from the use of band — shaped prestressing tendons.

3. The comparative analysis of the obtained results and the final conclusions

To carry out the analysis of the results of investigations the statical — and — strength calculations were made loading the tank wall with single prestressing tendons according to the accepted sequence of tensioning. The calculation method presented in the paper [2] was used for this purpose.

The value of the prestressing force N_v was determined basing on the measured strain values of the prestressing steel. The electric resistance wires were glued on three wires selected at random in each of the 15 tendons placed along the height of the tank wall between the pilasters No 7 and No 8.

The obtained results were worked up using statistical methods and the mean value, the standard deviation and the coefficient of variation were determined. Assuming that the mean value of strains to be decisive the value of effective prestressing force was calculated, which was equal to:

$$\bar{N}_v = \bar{\varepsilon} \cdot \bar{E}_v \cdot 18 \cdot F_v = 280.56 \text{ kN}$$

Taking into account many cracks in the tank wall occurring on the inside face except of two segments of wall which were made of concrete using the basalt aggregate (No 3 to No 5), the statical calculations were carried out for two different calculations scheme.

Scheme I

The tank wall made of concrete using basalt aggregate, slidingly jointed to foundation ring the friction coefficient being $\mu = 0.7$ and $\mu = 0.8$. The modulus of elasticity of concrete in bending was $E_b = 30000$ MPa

Scheme II

The tank wall made of concrete using granite aggregate was jointed in hinge type manner to the foundation ring. The modulus of elasticity of the concrete in bending was $E_b = 22500$ MPa.

For both calculations schemes the tank wall was considered to be a cylindrical shell of a constant thickness $t = 0.18$ m at the height of $H = 5.6$ m as well as to be cylindrical shell of thickness t at the height $H = 5.35$ m with the top stiffening ring of 0.25×0.38 m.

The obtained values of the tank wall displacements for both calculation schemes are given in the Table 1 as well as they are shown properly in Fig. 3 and 4.

The measured values of concrete strains in the compression along the section between the pilaster No 7 and 8 are shown in Fig. 5. When comparing the mean values of concrete strains with the distribution of circumferential forces the conformity of the nature of both curves is stated.

Taking into account the modulus of elasticity of concrete in compression to be $E = 27000$ MPa as well as the mean values concrete strains along the vertical section 3-3 (inside and outside of the tank wall) the experimental distribution of circumferential forces were determined and are shown in Fig. 5. The occurring differences may be explained by:

— the presence of pilasters, which bring disturbances in the static work of cylindrical shell,
— the increased strains of concrete, exerted by partial damage of the concrete structure due to the cracks appearing at several levels.

Basing on the executed analysis the following final conclusions can be presented:

— A special care must be taken of the quality of execution of the joint of wall and tank foundation ring. The effect of pilasters, which introduce considerable disturbances in the static work of shell can be eliminated to appreciable extent, if the sliding layer is executed carefully. The Fig. 2 exemplifies the comparison of radial displacements of the pilasters No 1 and No 8.
— The used sealing materials must not be used second time when further similar constructional and technological realizations are executed. Their presence within the joint of wall and bottom generated considerable increase of boundary disturbances corresponding with the coefficient of friction, $\mu = 0.7 \div 0.8$
— Prestressing of walls of the cylindrical tanks should be commenced at the bottom edge of the shell. If not, the discontinuity stresses, generated at the subsequent tensioning of tendons, combined with the boundary disturbances may exert the cracking of the tank wall, in spite of considerable displacements of the wall (see vertical section 0-0).

References

1. H. NOWAK, *The Influence of Deformability of the Bottom Edge of Shell on the Internal Forces Distribution in Concrete Tanks Prestressed by Separate Tendons Using Sectional System*, Ph. D. Thesis, Technical University of Cracow, 1971.
2. J. MICHNO, *Reaction of Prestressing Cable at the Cylindrical Tank Wall*, Inżynieria i Budownictwo, No 5, pp. 180 - 183, 1977.
3. A. SERUGA, *An Experimental Evaluation of the Internal Forces Distribution in Cylindrical Shells of Prestressed Concrete Reservoirs*, Ph. D. Thesis, Technical University of Cracow, 1978.
4. A. SERUGA, *Prefabricated Prestressed Concrete Tanks*, Inżynieria i Budownictwo, No 8 - 9, pp. 185 - 188, 1982.

Резюме

АНАЛИЗ НАПРЯЖЕННОГО СОСТОЯНИЯ В ЦИЛИНДРИЧЕСКИХ ОБОЛОЧКАХ БЕТОННЫХ РЕЗЕРВУАРОВ ПРЕДВАРИТЕЛЬНО НАПРЯЖЕННЫХ ВНЕШНИМИ КАБЛЯМИ

В публикации представлена оценка конструктивно-технологического решения цилиндрического резервуара емкостью $v = 5000$ м.^{3}, под действием нагрузки от предварительного напряжения внешними каблями 18 Ø 5 мм.

Сравнительный анализ экспериментальных и аналитических результатов дает основу для выводов относительно статической работы оболочек, а также технологии напряжения конструкции.

Streszczenie

ANALIZA STANU NAPRĘŻENIA W POWŁOKACH WALCOWYCH BETONOWYCH ZBIORNIKÓW SPRĘŻONYCH PASMOWYMI CIĘGNAMI ZEWNĘTRZNYMI

W pracy przeprowadzono ocenę rozwiązania konstrukcyjno-technologicznego zbiornika cylindrycznego o pojemności $V = 5000$ m³, sprężonego pasmowymi cięgnami zewnętrznymi typu 18 Ø 5 mm.

W oparciu o dokonaną analizę porównawczą wyników otrzymanych z badań doświadczalnych z wartościami obliczonymi, wysunięto wnioski końcowe dotyczące dalszego stosowania podobnych rozwiązań a także technologii sprężania konstrukcji.

Praca została złożona w Redakcji dnia 7 marca 1983 roku