INFLUENCE OF THE INTERMEDIATE STIFFENING GIRDERS UPON THE EFFORTS IN TOP ANGLE

Lyubomir Zdravkov
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1. Common position
The steel cylindrical tanks have thin walls and their shell must be assured against loss of stability. According to the normative rules and standards in Bulgaria now [1] it can be done only with the increase of the thickness of shell courses. In the methodology used in the foreign standards, the stiffening of the shell in the radial direction can be done by intermediate stiffening rings.
In [4], [5], [6], the necessary sections for top angle and intermediate stiffening girders must be calculated independently one from another without taking into account their mutual functioning.
The stiffening rings make the shell more stable, but it is interesting to determine whether intermediate wind girders influence on the wind and vacuum loads upon the top angle.

2. Creation of the model of steel vertical cylindrical tanks
For detailed research of the tank behavior the many three dimensioned computer model are created by means of SAP 2000.
The six typical tanks which volumes are respectively V100, V200, V300, V400, and V1000 are taken from [3] and are modeled by means of computer software. All the models have annular bottom plates (the bottom has not his central part), shell and stiffening rings. The tanks are opened (without fixed roof) and the shell is assured against the loss of stability by top angle, put in its upper point.
For the creation of all shell courses and annular bottom plates are used the Shell elements which thickness is **4 mm**. For the modeling stiffening rings are used Frame elements which have the following section modulus $\mathbf{W_g}$ for upper top angle and $\mathbf{W_i}$ for intermediate stiffening girders. Geometrical feature are determined according to [4].
The research upon the behavior of steel vertical cylindrical tank is carried out when the values of section modulus of top angle $\mathbf{W_g}$ is permanent and section modulus of the intermediate stiffening rings $\mathbf{W_i}$ is changeable.

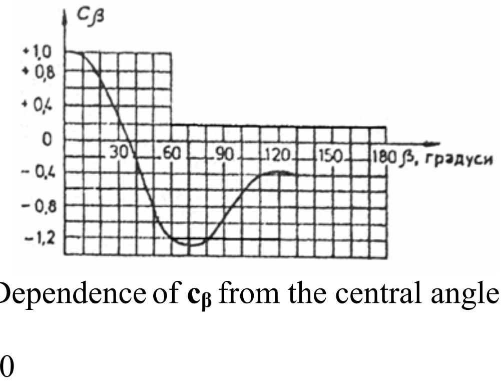
3. Pressure of the shell in the radial direction.
The pressure is shown in [2] and the tank is emptied from it's contain.

a) wind pressure

$w_n=v_m.k_2.c_e$ – normative value of wind pressure

v_w - normative value for the pressure by height

$c_e = k_1.c_\beta$ - coefficient which is accepted according to the following scheme when $Re>4.10^4$



Dependence of $\mathbf{c_\beta}$ from the central angle $\boldsymbol{\beta}$

When $c_\beta > 0$ coefficient $k_1 = 10$

When $c_\beta < 0$ coefficient K is shown on the table below and it depends on relation between height **H** and diameter **D** of the tanks

H/D	0,2	0,5	1	2	5	10	25
k_1 when $c_\beta < 0$	0,8	0,9	0,95	1,0	1,1	1,15	1,2

$w=w_n \,.\, \gamma_w$ – calculated value of the wind pressure

γ_v=1,4 – coefficient of over pressure of the wind pressure

b) vacuum load in the tank

$p_v = p_v^n.\gamma_v$ – calculated value of the vacuum loading in the tank

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

γ_n = 1,2 coefficient of over loading of vacuum.

4. Results

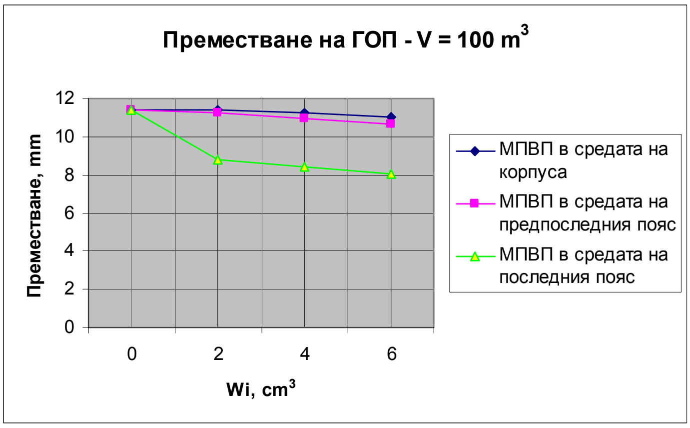
The calculated data are shown by graphics as function of section modulus of intermediate stiffening rings $\mathbf{W_i}$

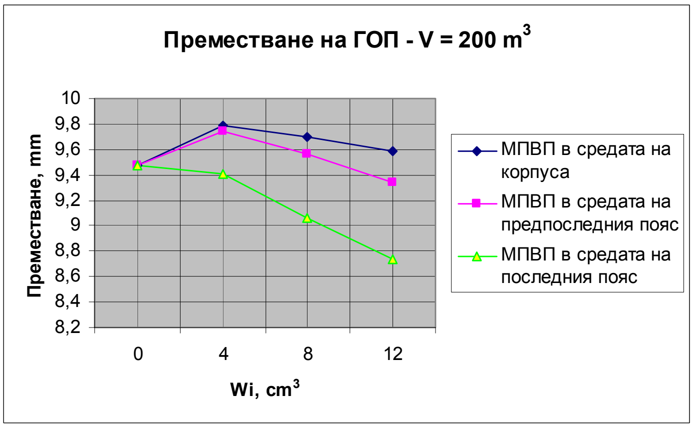
AST with capacity V = 100 m^3

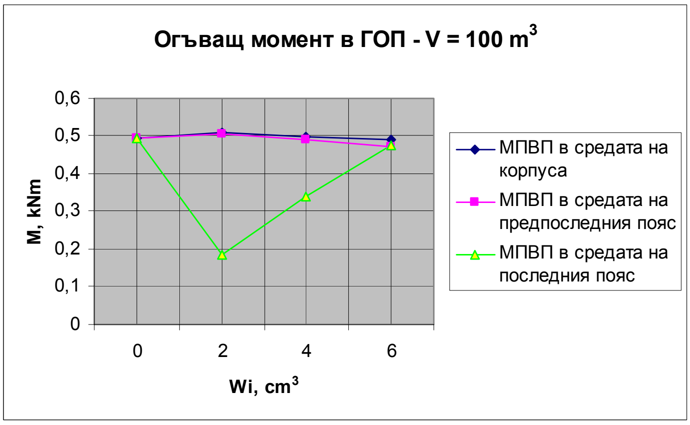
H = 5960 mm, D = 4730 mm ⟹ H/D = 1,260; k_1 = 0,963 when C_β < 0

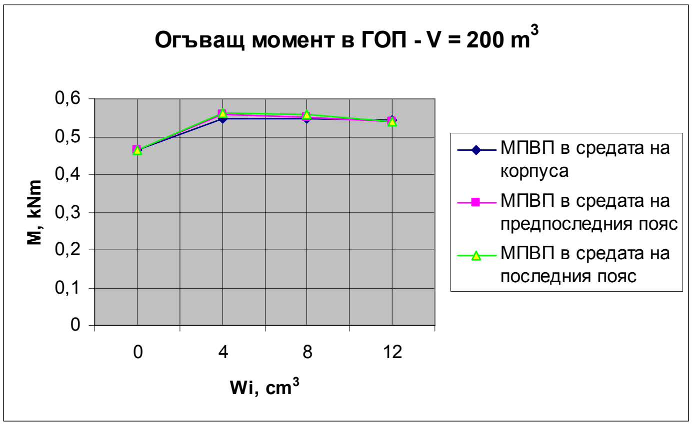
AST with capacity V = 200 m^3

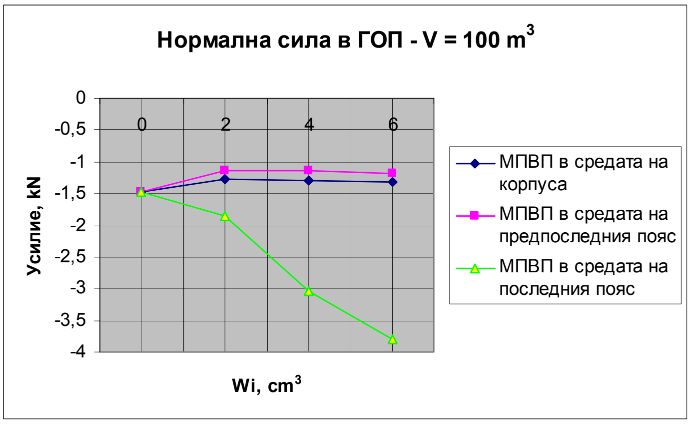
H = 5960 mm, D = 6630 mm ⟹ H/D = 0,8989; k_1 = 0,94 when C_β < 0

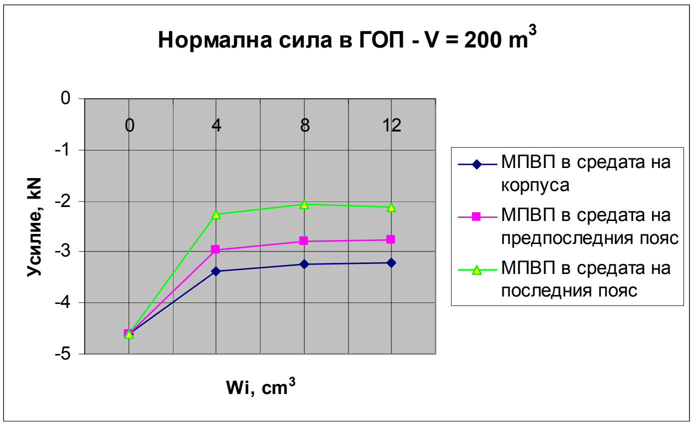










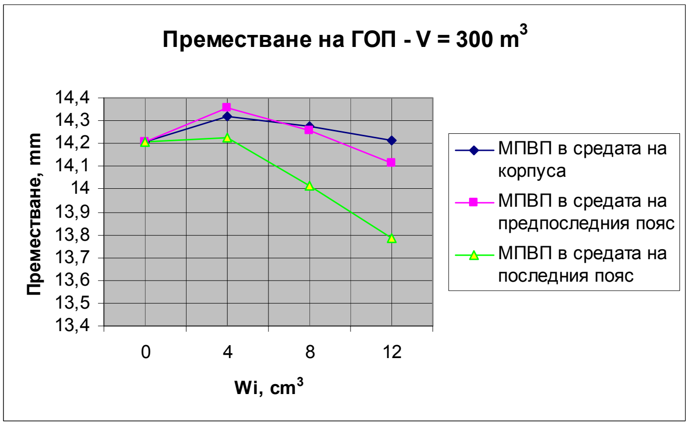


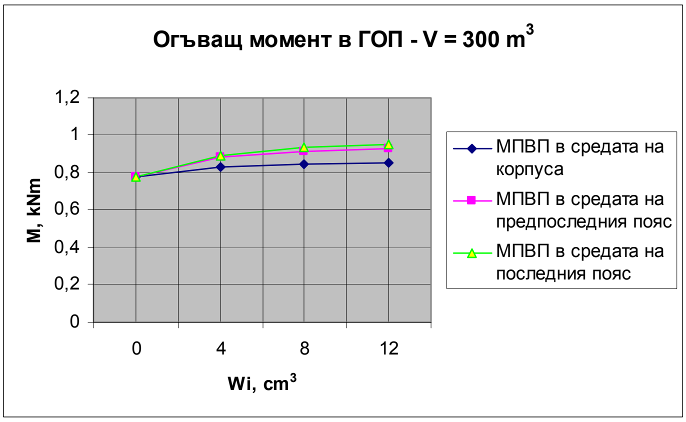
AST with capacity V = 300 m^3

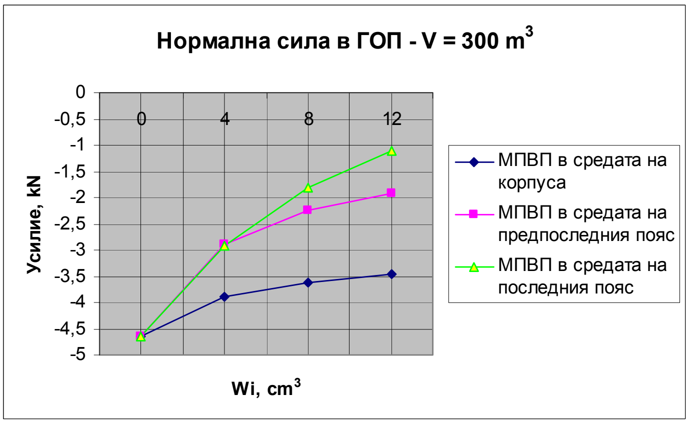
H = 7450 mm

D = 7580 mm

$\Rightarrow$ H/D = 0,983; k_1 = 0,948 when $C_\beta < 0$





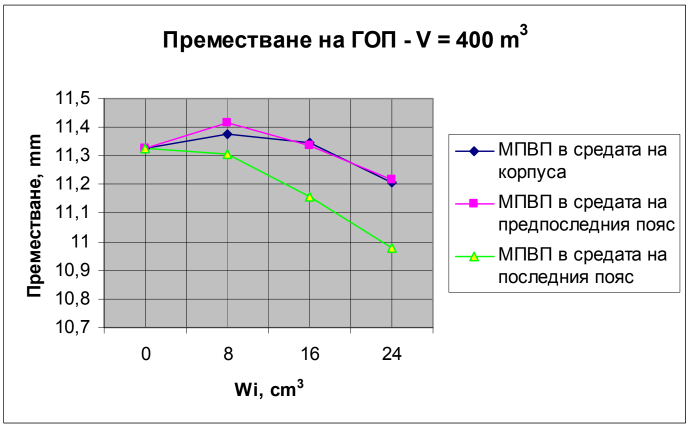


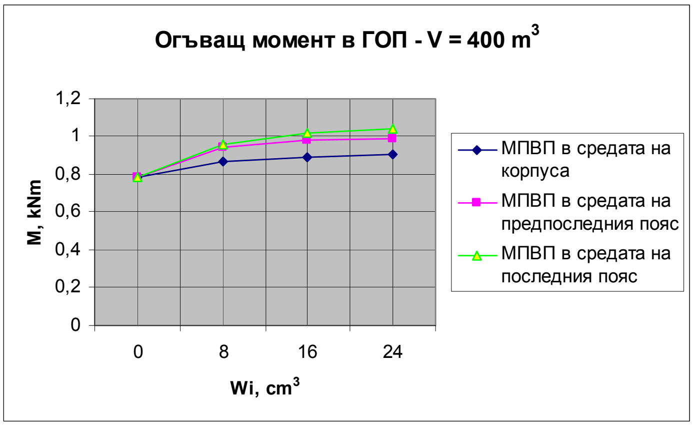
AST with capacity V = 400 m^3

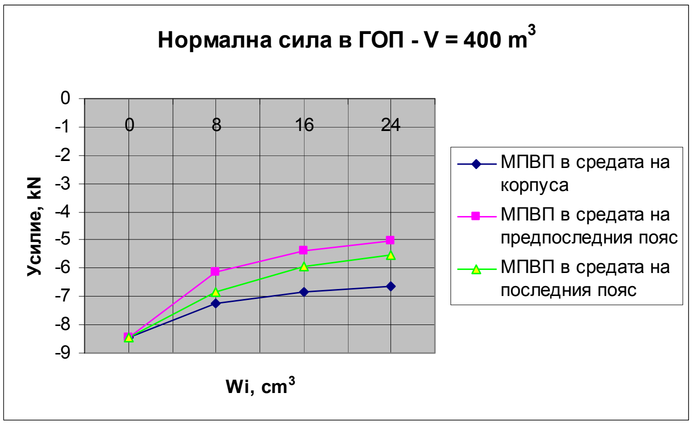
H = 7450 mm

D = 8530 mm

$\Rightarrow$ H/D = 0,8734; k_1 = 0,937 when $C_\beta < 0$





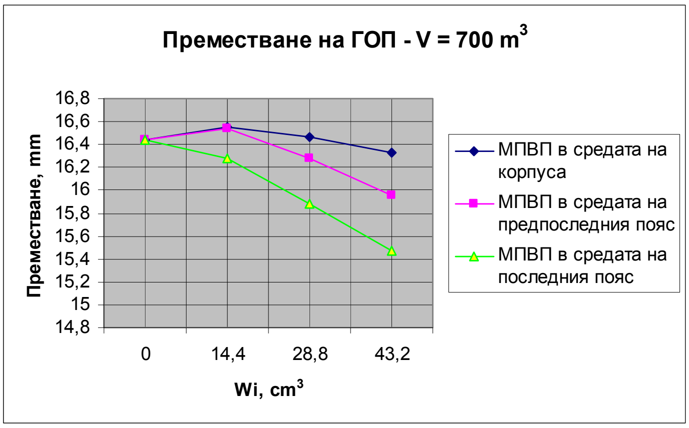


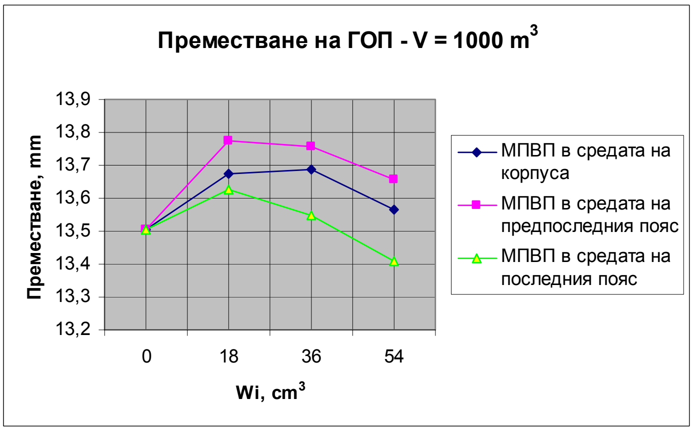
AST with capacity V = 700 m³

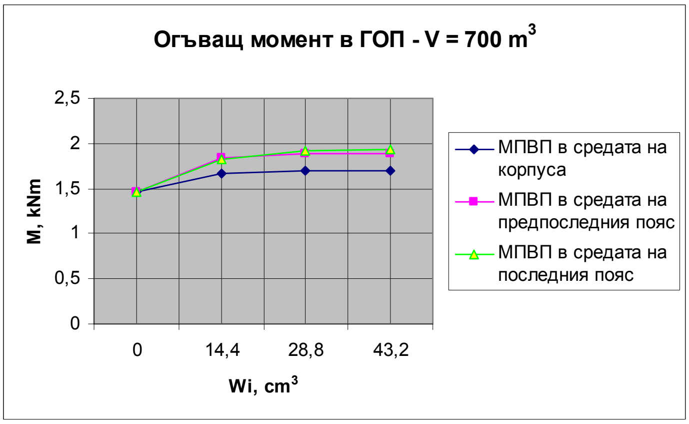
H = 8940 mm, D = 10430 mm ⟹ H/D = 0,8571; k_1 = 0,938 when $C_\beta < 0$

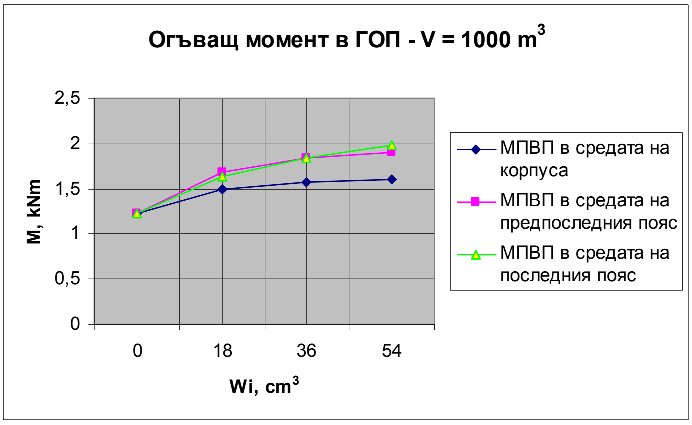
AST with capacity V = 1000 m³

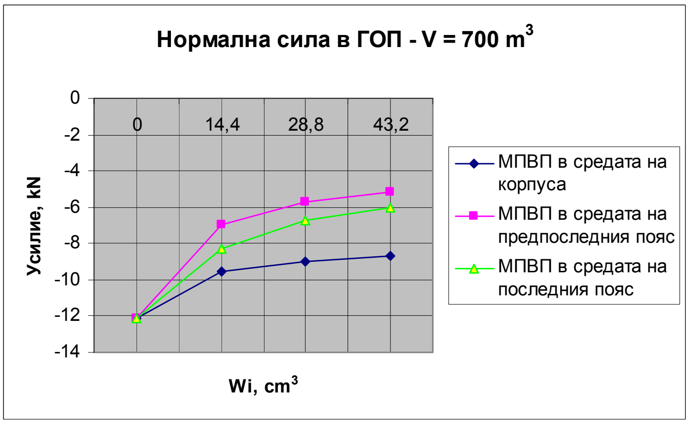
H = 8940 mm, D = 12 330 mm ⟹ H/D = 0,7251; k_1 = 0,922 when $C_\beta < 0$

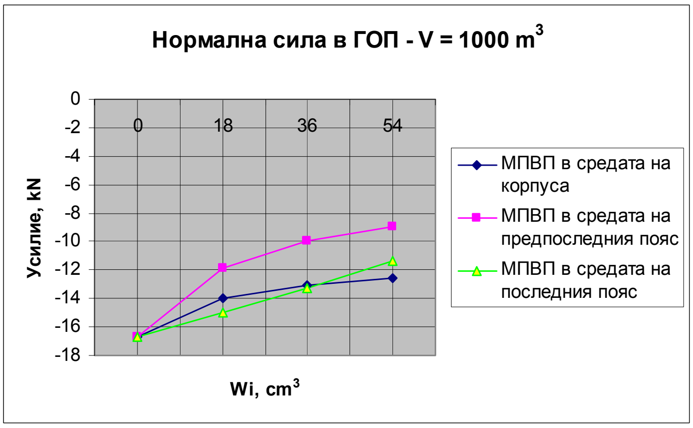












5. Conclusions:

a) when the distance between stiffening rings is smaller the influence of the intermediate stiffening rings upon the top angle is bigger;

b) when the $\mathbf{W_1}$ increases the bending moment **M** in the top angle increases too;

c) when the $\mathbf{W_1}$ increases the pressure effort **N** in the upper supporting rings decreases;

d) the action of **M** and **N** in the same time upon the top angle is more unfavorable when the intermediate stiffening rings are closer positioned and when the section modulus $\mathbf{W_i}$ in the intermediate rings is bigger;

The intermediate stiffening rings have unfavorable influence upon the top angle.

e) absolutely movement of top angle increases when the intermediate rings have small stiffness. When $\mathbf{W_i}$ increases the movement decreases.

f) the interaction between upper and intermediate rings is slightly expressed and the methodology accepted in [4], [5], [6] for independent determination of their necessary sections is convenient but with big reserve of security.

6. Литература

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