

# The Mendeleev-Klayperon Equation in Estimation of Pressure on Box Spans in Enclosed Spaces of Pedestrian Bridges

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**Abstract.** Practical use of building structures with enclosed spaces is determined by their corrosion resistance requirements. These requirements are implemented and applied in closed spaces spans for pedestrian bridges built in Khabarovsk in Gogol and P. Morozov streets. Implementing of such a constructive solution raises a question of climatic factors effect on confined space and as a result the strain-stress state of the box-shaped span. The article deals with the issue of changing the pressure inside a closed loop span of pedestrian bridge when the ambient temperature changes. The amount of distributed pressure on the elements of a box span was defined on the basis of the Mendeleev-Klayperon equation. The results of stress state change of box-shaped span elements with a closed space depending on the ambient temperature changes were achieved by means of numerical simulation.

## Introduction

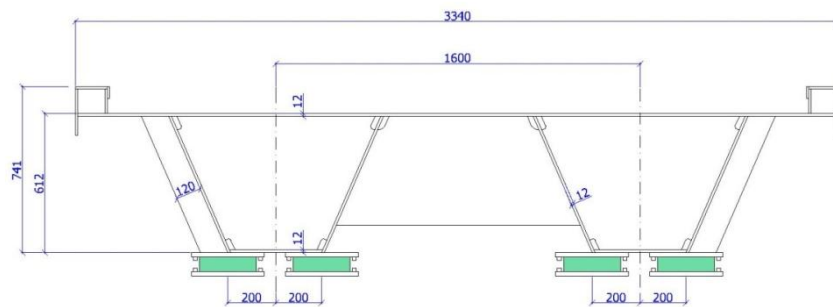
The actuality of the research conditions is predetermined by p. 8.2. [8] with regard to ensure the sealing of fully closed profiles of elements and blocks.

The attention in considering this idea is emphasized with a help of already completed box spans constructions with an enclosed space pedestrian overpasses over Gogol street at Lenin square (fig. 1,2) and over P. Morozov street to the Ice Palace "Erofev arena" (fig. 3,4) in Khabarovsk city.

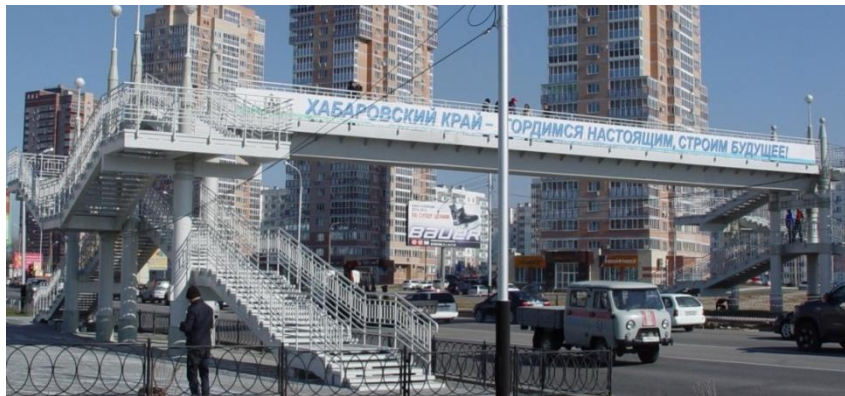


**Figure 1.** Side view of the structure of pedestrian bridge span in Gogol street at Lenin square.

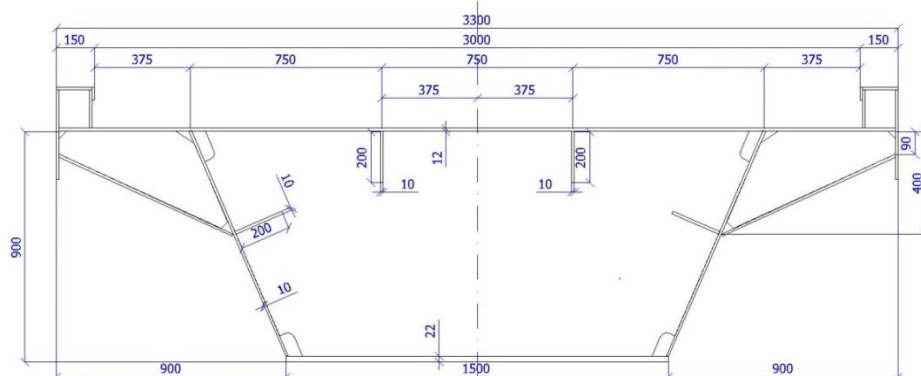




**Figure 2.** Cross-section of pedestrian bridge span in Gogol street at Lenin square.



**Figure 3.** General view of the pedestrian bridge in P. Morozov street near the Regional Palace of Bandy "arena" Erofej".



**Figure 4.** Cross-section pedestrian bridge span in the P. Morozov st. near the Regional Palace of Bandy "arena" Erofej».

A clear need to determine the pressure of surface forces at the enclosed spaces follows from the requirements of normative documents estimating the sustainability of web plates, with joint action of vertical loads and forces of the surface pressure, caused by the impact of environment, it may be assumed that the combination of these factors can actualize the power issue of web plates rigidity or initiate constructive interference regarding control of their rigidity.

To estimate the magnitude of the surface pressure force caused by the impact of environment the dependency based on equation of Mendeleev-Klayperon was taken up:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \quad (1)$$

In the run-up to the quantification of environmental effects on enclosed spaces the qualitative analysis in the initial phase of dependencies (1) and the establishment of the dominant factors of influence on the magnitude of environmental impacts seem appropriate.

In this connection, it should be noted that in case of a relatively large stiffness of elements (walls, top and bottom plates, forming the outline of the box section) as a first approximation at the first step in solving the problem, you can assume a small dependence of the amount of the enclosed space from the pressure changing  $P$ , and thus to accept a constancy  $V_1 = V_2$ , and to accept the ambient temperature as the predominant factor influencing the amount of surface pressure. And in the summer we need to take into account the direct effect of sunlight on the temperature of the metal structures and obviously equal temperature within enclosed space of a box span.

Define air temperature in periods of time reflecting specific stages of formation and operation of box-shaped span with enclosed spaces on the one hand and at the same time determining the greatest outrage in a constructional enclosure limiting the enclosed space in the span.

In this manner, in accordance with paragraph 6.27 [8] and in the light of [5] for the region of Khabarovsk we have:

standard value of the temperature in the warm season

$$T_{nT} = t_{VII} + T = 21,1 + 8 = +29,1^\circ\text{C}$$

In determining  $t_{nT}$  as aerial environment temperature in enclosed spaces guiding surface forces, obviously, accounting the effects of solar radiation estimated at p. 6.27 [8] by additional construction heating at the amt  $\Delta t = 10^\circ\text{C}$  is required, that is obviously affecting the air temperature in an enclosed space box span.

In this way, the standard value of the temperature in the warm season can be taken as:

$$t_{nT}^* = t_{VII} + T = 21,1 + 8 + 10 = +39,1^\circ\text{C}$$

The standard value of the temperature in the cold season  $T_{nX}$  in accordance with the instructions of p. 6.27 [8] and in the light of p. 5.39 equals expected value as for p. 5.39 based on [5]

$$T_{nT} = -34^\circ\text{C}$$

Temperature of construction locking in warm season

$$t_{3T} = t_{nT} - 15 = 21,9 - 15 = +14,1^\circ\text{C}$$

Temperature of construction locking in cold season

$$t_{3X} = t_{nX} + 15 = -34 + 15 = -19^\circ\text{C}$$

When choosing the counting start for estimating extreme temperature swings we take into account that the creation of enclosed spaces in the box span will be provided with the appliance of blind welds along the entire perimeter of a supporting diaphragm contact with the walls, top and bottom sheets of a box span, and it's likely to be the temperature of the warm season, as  $t_{3T} = 14,1^\circ\text{C}$

On the basis of the temperature values at fixed points of time, reflecting the typical stages of construction and the conditions for its operation in a particular way it's possible to mark the following time intervals, fitting in with temperatures and temperature changes.

1 combination:

The temperature of the locking  $t_{3T} = +14,1^\circ\text{C}$  up to the operating temperature in the cold season with temperatures  $t_{3X} = -34^\circ\text{C}$

2 combination:

The temperature of the locking  $t_{3T} = +14,1^\circ\text{C}$  up to the operating temperature in the warm season, taking into account the influence of solar radiation  $t_{nT}^* = +39,1^\circ\text{C}$

The impact of local effects of sunlight may be even higher.

The following entry is equal to the equation (1):

$$P_1 V_1 T_2 = P_2 V_2 T_1 \quad (2)$$

From which pressure P2 other than pressure P1 and reflecting the change of ambient environment temperature.

With P2 as  $P_2 = P_1 + \Delta P$  dependency (1) acquires the form of equation:

$$\frac{P_1 V_1}{T_1} = \frac{(P_1 + \Delta P) V_2}{T_2} \quad (3)$$

At relatively greater rigidity of the frame plates that make up the outline of the box section, we can assume as the first step to approximation to the solution of the problem a small dependence of the volume of the enclosed space from the pressure P, and in this way the following equation can be assumed correct  $V_1 = V_2$ . Then  $\Delta P$  is given from the equation:

$$\Delta P = \left( \frac{P_1}{T_1} - \frac{P_1}{T_2} \right) \cdot T_2, \text{ где}$$

$T_1$  - the temperature of span installation (288.15 K [15 oC]);

$P_1$  - atmospheric pressure; (1.066 Pa for summer and 0.826 Pa for winter);

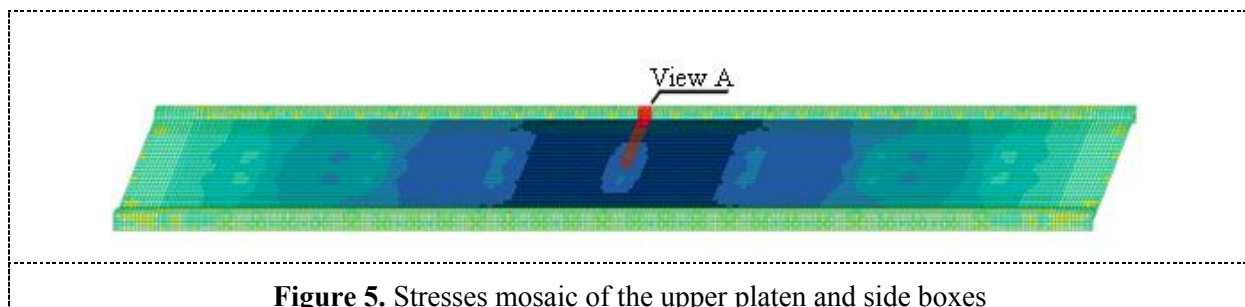
$T_2$  - the maximum and minimum operating temperature 312.25 K (39.1 oC) for summer and 239.15 K (-34° oC) for the winter, [6];

$\Delta P_s = 0.093 \text{ Pa} = 9.48 \cdot 10^{-6} \text{ t/m}^2$ ;

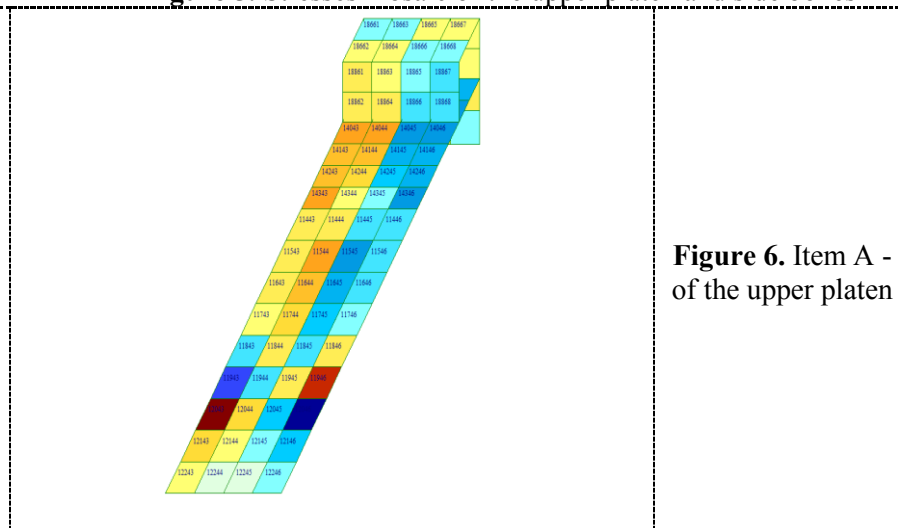
$\Delta P_w = -0.141 \text{ Pa} = 14.38 \cdot 10^{-6} \text{ t/m}^2$ ;

For the evaluation of thermal effects on the stress-strain state of the pedestrian bridge span over P. Morozov street to the Ice Palace "Erofev arena" in Khabarovsk was created a numerical model in PC Lira. 3-d model of the span was created as flat finite elements. The span structure was loaded with pedestrian load size 400kgf/m<sup>2</sup> and distributed pressure from environmental temperature changes at box section elements. The results of numerical simulation of box-shaped span with an enclosed space are shown in figures 5-12

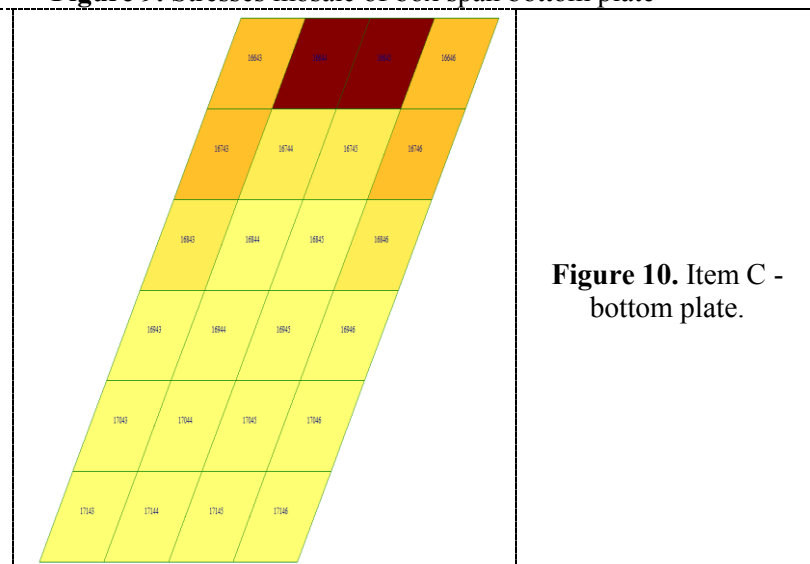
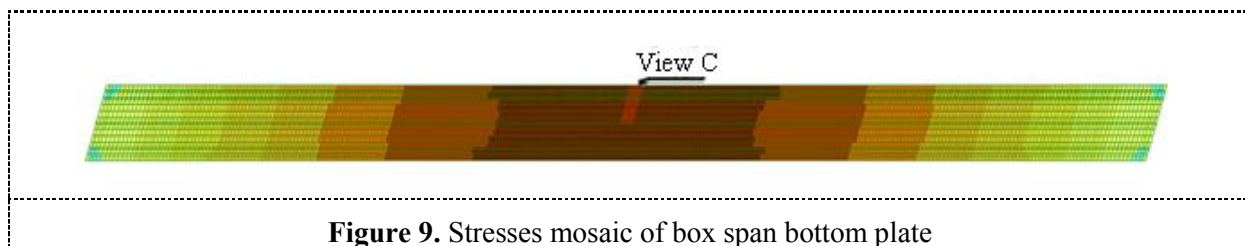
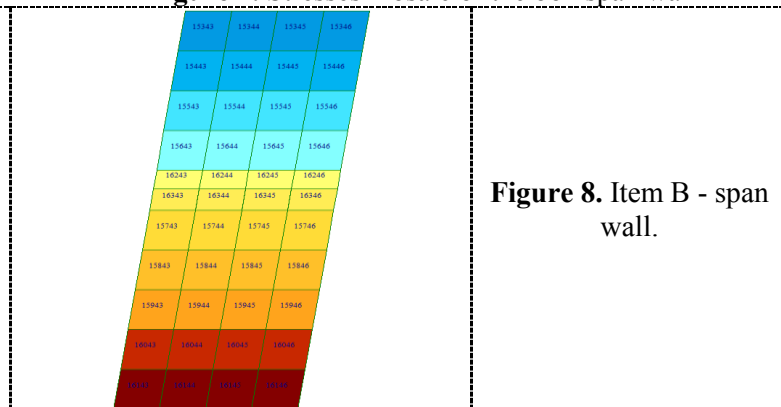
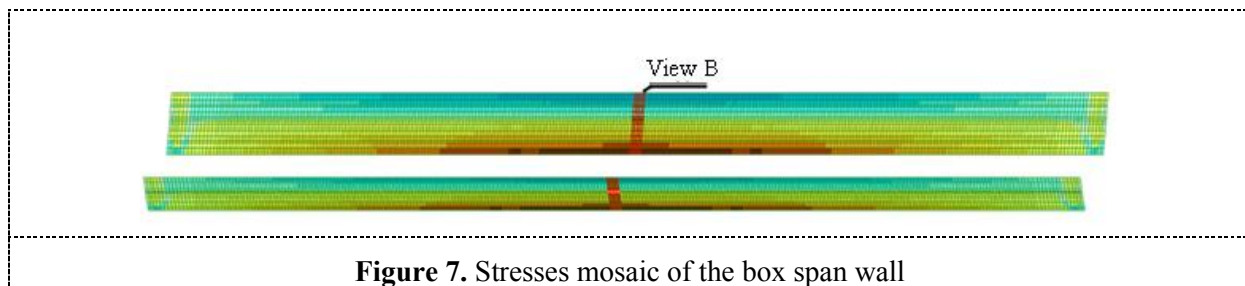
### The results of the evaluation of stress stated bearing elements of the box span



**Figure 5.** Stresses mosaic of the upper platen and side boxes



**Figure 6.** Item A - of the upper platen



Numeric values of stresses in box span finite elements of selected sections are specified in the tables. 1-3.

**Table 1.** The stress values of the upper plate elements (View A), tf/m<sup>2</sup>

№FE	Own weight, bridge floor and pedestrians (excluding temperature)			Own weight, bridge floor and pedestrians (summer period, $t = 39.1^{\circ}\text{C} = 312.25\text{ K}$ )			Own weight, bridge floor and pedestrians (winter period, $t = -34^{\circ}\text{C} = 239.15\text{ K}$ )		
	Nx	Ny	$\tau_{xy}$	Nx	Ny	$\tau_{xy}$	Nx	Ny	$\tau_{xy}$
12244	-7419.810	-146.512	-0.078	-7419.797	-146.512	-0.078	-7419.829	-146.512	-0.078
12144	-7228.143	-252.001	16.150	-7228.131	-252.000	16.150	-7228.160	-252.002	16.150
12044	-6668.200	-546.951	144.795	-6668.192	-546.948	144.793	-6668.212	-546.954	144.796
11944	-6741.932	-560.959	-77.148	-6741.924	-560.957	-77.148	-6741.945	-560.963	-77.149
11844	-7460.989	-295.215	62.233	-7460.976	-295.215	62.232	-7461.008	-295.216	62.233
11744	-7846.695	-201.127	103.276	-7846.679	-201.127	103.276	-7846.717	-201.127	103.277
11644	-8113.677	-162.642	151.485	-8113.660	-162.643	151.485	-8113.702	-162.641	151.486
11544	-8372.972	-74.263	218.220	-8372.953	-74.264	218.219	-8372.999	-74.261	218.221
11444	-8478.563	451.959	69.028	-8478.543	451.956	69.028	-8478.591	451.963	69.028
14344	-8692.786	-275.612	37.121	-8692.766	-275.613	37.121	-8692.815	-275.611	37.121
14244	8564.038	-189.634	137.840	8564.019	-189.636	137.840	8564.066	-189.633	137.840
14144	-8554.611	-171.416	180.205	-8554.592	-171.417	180.205	-8554.641	-171.414	180.205
14044	-8544.771	-172.974	198.643	-8544.752	-172.975	198.643	-8544.800	-172.972	198.643

**Table 2.** The stress values at the elements of the side wall (View B), tf/m<sup>2</sup>

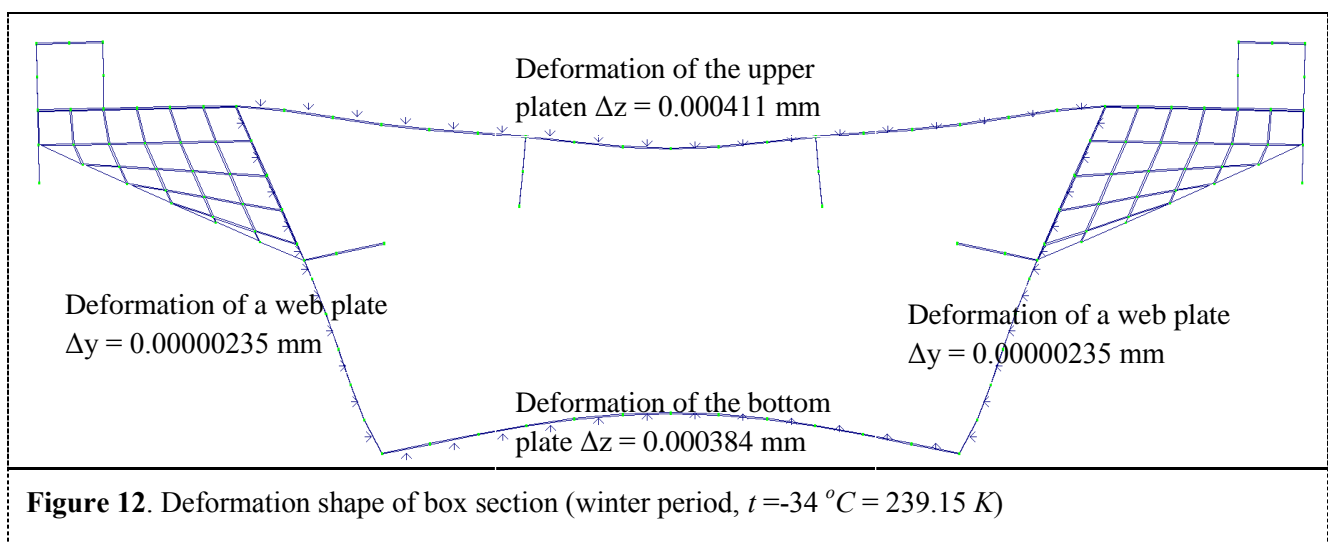
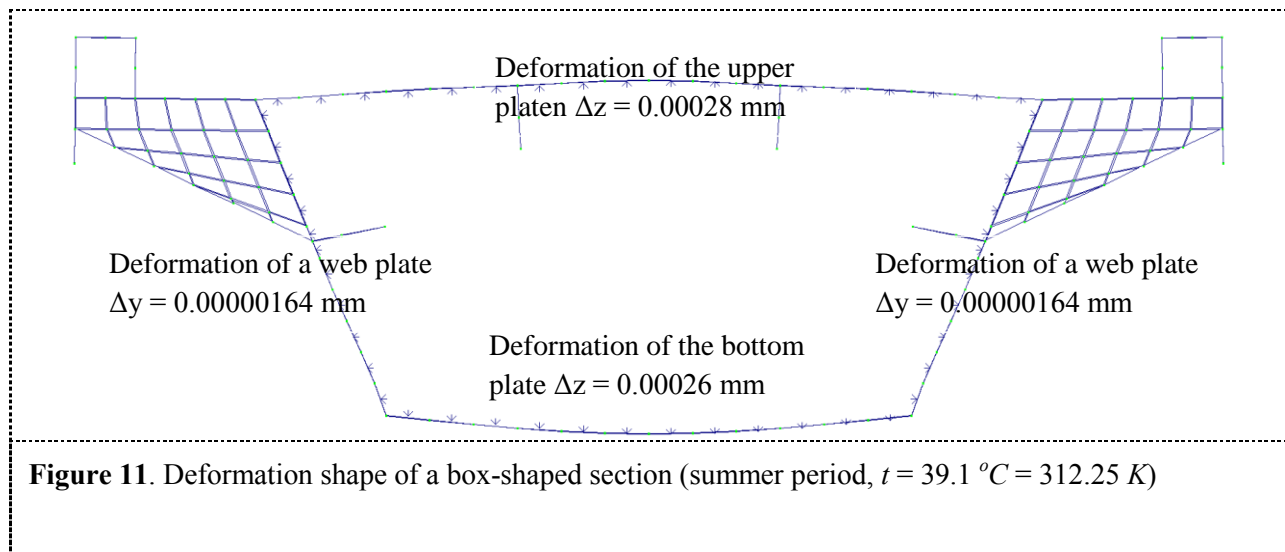
№FE	Own weight, bridge floor and pedestrians (excluding temperature)			Own weight, bridge floor and pedestrians (summer period, $t = 39.1^{\circ}\text{C} = 312.25\text{ K}$ )			Own weight, bridge floor and pedestrians (winter period, $t = -34^{\circ}\text{C} = 239.15\text{ K}$ )		
	Nx	Ny	$\tau_{xy}$	Nx	Ny	$\tau_{xy}$	Nx	Ny	$\tau_{xy}$
16144	13474.951	1969.523	1124.596	13474.920	1969.518	1124.593	13474.998	1969.531	1124.601
16044	10293.176	1591.544	657.058	10293.152	1591.540	657.056	10293.211	1591.550	657.061
15944	7962.591	1342.488	327.864	7962.572	1342.485	327.862	7962.618	1342.493	327.866
15844	5711.027	994.103	127.969	5711.013	994.101	127.968	5711.047	994.107	127.971
15744	3514.161	659.104	21.055	3514.152	659.104	21.054	3514.175	659.106	21.056
16344	1844.210	411.048	-12.863	1844.203	411.049	-12.864	1844.220	411.047	-12.862
16244	758.328	266.623	-19.376	758.324	266.624	-19.376	758.335	266.622	-19.375
15644	-847.755	82.163	3.724	-847.755	82.164	3.723	-847.756	82.162	3.725
15544	-3048.985	-139.265	70.462	-3048.979	-139.264	70.461	-3048.994	-139.266	70.464
15444	-5251.256	-262.718	173.260	-5251.245	-262.717	173.259	-5251.273	-262.719	173.262
15344	-7605.596	-394.408	313.908	-7605.578	-394.407	313.907	-7605.622	-394.410	313.911

**Table 3.** The stress values at the elements of the bottom platen (View C), tf/m<sup>2</sup>

№ FE	Own weight, bridge floor and pedestrians (excluding temperature)			Own weight, bridge floor and pedestrians (summer period, $t = 39.1^{\circ}\text{C} = 312.25\text{ K}$ )			Own weight, bridge floor and pedestrians (winter period, $t = -34^{\circ}\text{C} = 239.15\text{ K}$ )		
	Nx	Ny	$\tau_{xy}$	Nx	Ny	$\tau_{xy}$	Nx	Ny	$\tau_{xy}$
17144	13334.392	838.150	-32.628	13334.362	838.148	-32.628	13334.436	838.153	-32.629
17044	13345.316	853.095	-102.258	13345.287	853.093	-102.258	13345.360	853.098	-102.259
16944	13371.194	883.138	-185.143	13371.164	883.136	-185.143	13371.238	883.142	-185.144
16844	13432.219	934.795	-294.819	13432.188	934.793	-294.818	13432.264	934.799	-294.820
16744	13561.980	998.054	-479.946	13561.950	998.051	-479.944	13562.026	998.058	-479.948
16644	14362.020	989.134	-708.974	14361.986	989.131	-708.972	14362.068	989.138	-708.976

**The results of the evaluation of the strained state of box span bearing elements**





### Conclusions.

The achieved results of numerical solutions at estimating the stress state of shell structure elements in enclosed spaces permit to register a negligible impact of pressure caused by ambient temperature change. However, in the case of the developed sizes of box span section and definitely relatively large sizes of enclosed space shells, bending moments in the top, bottom platen and web plates of box span obviously become significant as elements that form the construction of the enclosed space shell. This issue definitely will gain relevance when engineering practices will ensure the airtight packing for erection joints and we may suppose this is a matter of the nearest future. Herein we already know the examples of practical development of pressure-proofed erection joints accompanied with enclosed spaces at the span elements of modern development, enclosed spaces represent the longitudinal beams, supporting covering sheets of orthotropic plate deckings.

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