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# CALCULATION AND DESIGN OF THE LARGE VOLUME TANKS EXPOSED TO SEISMIC LOADS

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## ABSTRACT

The widespread use of vertical cylindrical tanks puts the question of their sustainable design. Snow load brings the greatest contribution to the stress-strain state of the supporting structures of vertical tanks spherical domed coatings. The coefficients of the external pressure on the walls and coating of the wind were also determined. The obtained results can be used to develop effective design solutions for domed coatings of the oil tanks.

**Key words**: Seismic load, Cylindrical tank, Stress-strain state.

## INTRODUCTION

In the recent time, a clear tendency to build large volume tanks of 50,000 to 100,000 $m^3$ with double-deck floating roofs has been traced. Most frequently the construction areas of such tanks are critical both from climatic (snow, wind, ice storm) and seismic point of view.

During the design stage of the double-deck floating roof two alternative engineering, fabrication and installation concepts are implemented[1]:

(i) Standard solution using plate-by-plate method when the greater part of the roof assembly and welding works is performed on site. The roof consists of two decks: upper and lower decks interconnected by a number of concentric rings that form ring cells. The external cell is separated by radial partition walls to form leak-proof boxes (Fig. 1).

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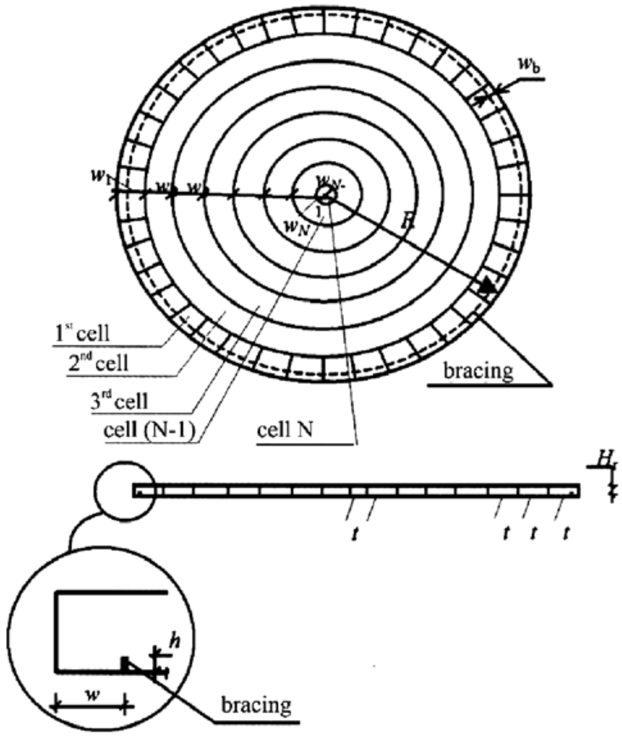



**Fig. 1: Structural layout of floating roof**

(ii) New solution using installation method of the factory-assembled rectangular boxes. The boxes are radially oriented towards the centre of the tank. The spaces between the boxes are covered with plate-by-plate panels on the upper and lower decks during the installation (Fig. 2).

Thus the main difference between these design layouts of the roofs is the division principle into ring or radial cells.

In accordance with the design rules the tank roof shall be stable, floating and robust when at least two adjacent cells are no more leak-proof and the outside load equally or non-equally distributed acts on the upper deck (Fig. 3).

Distinguishing design characteristic of the vertical cylindrical tanks of the large volume is that as the diameter of the structure increases curvature of the cylindrical wall and hence its rigidity significantly decrease[2].

When such tanks are constructed in the seismic regions and in the high wind/snow areas reliability of the structural design and engineering is of great importance[3].

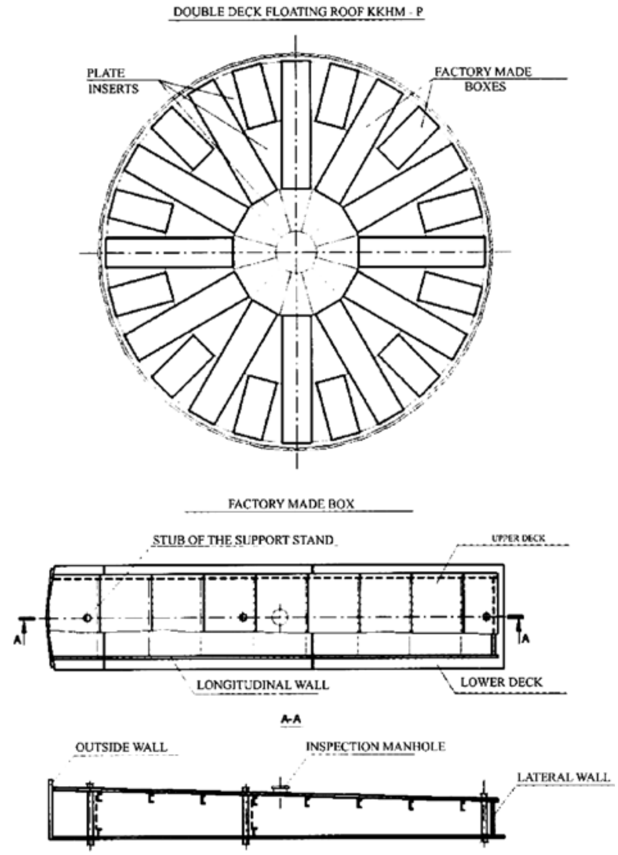
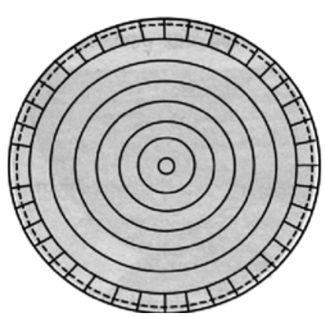
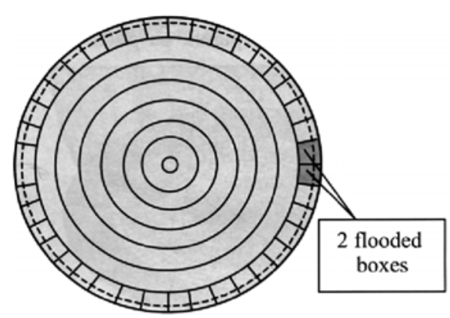



**Fig. 2: Settlement scheme of a roof**

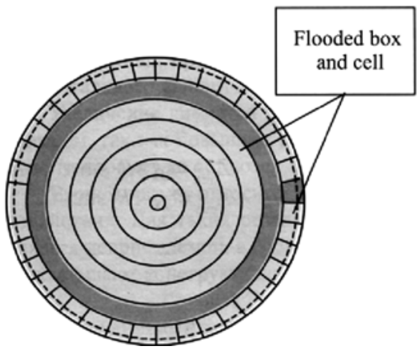


**Design combination 1 dead weight of the roof ($p_r + p_w$), snow ($p_s$ = 3.20 kPa) uniformly on the entire surface**

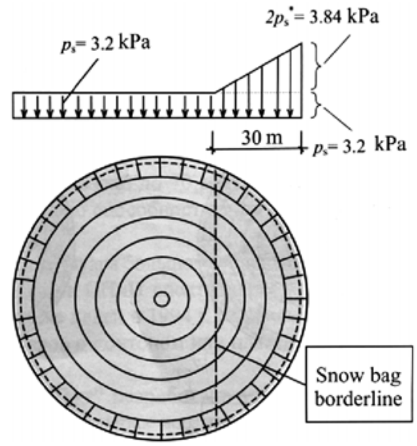



**Design combination 2 dead weight of the roof ($p_r + p_w$), snow ($p_s$ = 3.20 kPa) uniformly on the entire surface, 2 flooded boxes of external cell**

Cont…




**Design combination 3 dead weight of the roof ($p_r$ + $p_w$), snow ($p_s$ = 3.20 kPa) uniformly on the entire surface, 1 flooded box of external cell and flooded sec. cell**




**Design combination 4 dead weight of the roof ($p_r$ + $p_w$), snow ($p_s$ = 3.20 kPa) uniformly on the entire surface, snow bag (SNiP 2.01.07-85)**

**Fig. 3: Design combinations of the effects on the floating roof**

Development and testing of the tank calculation methods that meet the latest global requirements of the engineering science are also essential.

Experience with various software products has shown that application of ANSYS computer system is the most effective for the calculation of the tank structures. Basic software package for calculation of the tank wall, fixed and floating roofs, individual assemblies such as tie-ins, etc was launched in the last several years within ANSYS computer system. This software is provided with the strength and stability control units. Software programs have coded representation, that is to say letters, which do not require re-programming and ensure fully automatic calculations when initial data are measured.

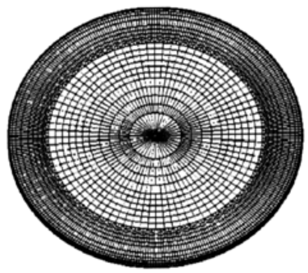
This reduces design period significantly. The example and calculation results of the floating roof are shown below.

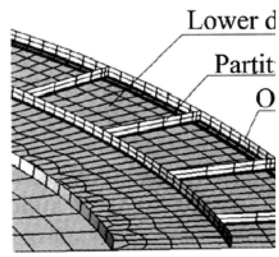
Finite element calculation pattern of the floating roof is illustrated in Fig. 4.

Two consecutive tasks shall be solved for structural calculations:

- Floatability control, in other words determination of the roof equilibrium position in the liquid under the snow load with the account of possible leakage in several cells;

- Strength control of the roof structural elements at the equilibrium position obtained.






**a) calculation pattern** **b) segment**

**Fig. 4: Model engineering of the floating roof using finite element method**

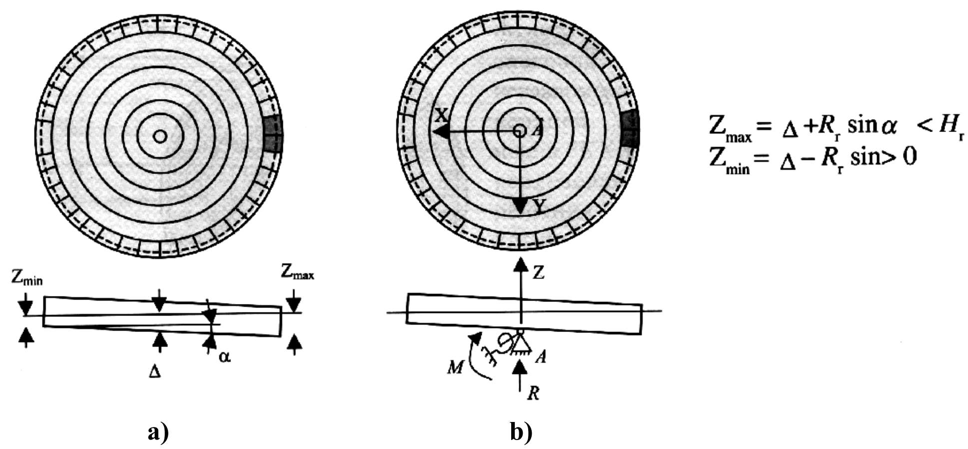



**Fig. 5: Determination of the roof static equilibrium position: (a) Static equilibrium position; (b) Calculation pattern for determination of the roof static equilibrium position using deflection method**

Task solving gets complicated since there are no external bracings in the floating roof, and such structure is considered unstable from the structural mechanics point of view. It is commonly known that application of the computer systems is no longer possible in this case[4]. Universal special technique has been developed which allows for application of this calculation method. It is based on the iterative approach and enables determination of the roof depth rate Δ, roof swing α (Fig. 5) and all components of the stress and strain state for any design variant for the roof or pontoon. Widely recognized deflection method forms the basis of this technique. Two additional bracings are introduced into the calculation pattern, one of the bracing prevents from vertical movement, and the other bracing does not allow the roof to turn (Fig. 6).

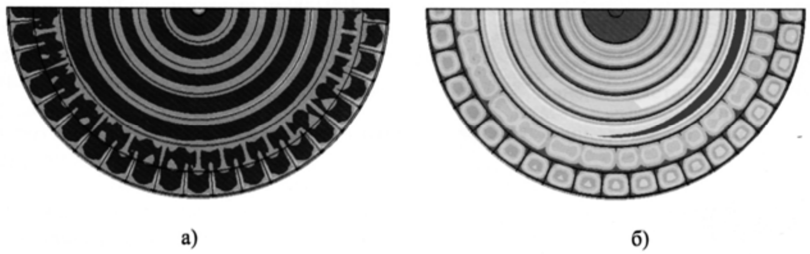



**Fig. 6: Calculation results of the floating roof (a) travel of the lower deck; (b) equivalent stresses of the lower deck elements**

The bracings introduced make the system stable and allow for various calculation methods, including finite element method[5].

Based on the software developed the calculations have been made for the double-deck floating roofs of different geometrical dimensions under the wide range of snow loads. Researches demonstrate that when the tank diameter increases the advantage of the floating roofs versus fixed roofs becomes undeniable even if snow bags occur. Large diameter fixed roofs require additional supports to be installed inside the tank which reduce snow load on the tank wall during static loading, however are ineffective under horizontal seismic loads. Increase of the floating roof diameter up to 70 m is a favourable factor since it enhances roof floatability and load-carrying ability; when diameter is greater than 75 m these parameters remain unchanged[6].

Application of the corrected calculation patterns throughout the design stages of the tanks allows for detailed research and true and reliable evaluation of the structural stability and strength. The calculations performed have confirmed the possibility to install steel cylindrical tanks of 100 000 $m^3$ in the seismic areas with high snow and wind loads.

## CONCLUSION

Today in the territory of Kazakhstan more than 10 thousand tanks for storage of oil and oil products are located, and the tendency to increase in their quantity is observed. Now normative documents recommend touse spherical and conic domes of various constructive schemes as stationary coverings of cylindrical tanks. Thus norm don't forbid to use as stationary coverings of tanks of a roof and other forms.

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