The assessment of the tank foundation carrying capacity under the conditions of seismic danger

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Abstract. The article is devoted to the preliminary assessment of the tank foundation for its carrying capacity and durability as long as this structure is of a high responsibility level. The inspection of the tank foundation was made in order to assess the possibility of building a similar construction. Considering the site conditions, special attention was paid to the seismic stability of the tank. According to the state standard requirements the calculations were made on the basis of all index marks taking into account the main and specific combinations of loads. To define the tank stability for further operation, it was necessary to assess the possible need of strengthening or repairing it from the point of view of its carrying capacity for the first group of limit states as well as the deformed state. By the results of the research the possibility to further re-use the construction has to be resolved by the owner.

1 Introduction

The reuse of those buildings decommissioned on various reasons requires a preliminary assessment of their technical condition. The author of this article made this preliminary assessment of the foundation for a clean water tank being under reconstruction. Clean water reservoirs are considered to be buildings of a high responsibility level according to the Technical safety regulations of buildings and structures of the Federal Law No. 384-ФЗ dated December 30, 2009 [1]. They are also considered buildings of an especially high responsibility level (1a) according to the State Standard P 54257-2010 named "The Reliability of Building Structures and Foundations. Main Requirements" [2].

The aim of the research is to calculate the carrying capacity of the existing clean water tank foundation for building on its basis a 10-meter high structure. The calculation was made on the basis of the General Practice named "The Methodology of Inspection of Tank Foundations and Bottoms" approved and enacted by the order of "Transneft" company on October 8, 2007 [3].

The scientific novelty of the research is to study the possibility of re-using the existing tank foundation for building a new structure of an especially high responsibility level. Such studies have never been carried out before.

Initial data for the calculation.

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1.1 Operating load values

The territory is located in climatic region I, the subarea - I A. The climate of the region is sharply continental with a cold long winter and a comparatively short warm summer.

Natural and climatic conditions of the area:

- it is region IV according to the weight of snow cover where the estimated value of snow cover weight is 2.4 kilopascal
- it is region I according to the high-speed wind pressure with the standard value of wind pressure of 0.23 kilopascal.
- the category of soils by their seismic properties is II;
- taking into consideration the results of seismic micro-zoning and the responsibility level of the facility, the construction site seismicity is estimated at 8 points.

1.2 The results of the foundation soils investigation

The construction site is a weakly dissected, steeply-sloping plain composed of Jurassic sandstones. From the geomorphologic point of view, this territory is located on the watershed of rivers where the total slope of the surface is 1-2 °.

The site is planned and sprinkled with bulk soils formed as a result of the construction of the micro-district. For this reason the natural ground contour was not preserved. The elevation marks of the surface within the site vary from 839.33 to 842.40 m (according to the Baltic Height System), the height difference is 3.07 m.

Geocryologically, the sites are located in the zone of island development of permafrost composed of thawed soils. The soil temperature at the depth of zero amplitudes (10 meters) varies from plus 6.2 ° C to plus 6.4 ° C.

As a result of the spatial variability analysis of particular values of soil properties, index marks were determined by the laboratory methods. After studying the geological structure data along with lithological features of the soils, the following 5 engineering-geological elements (EGEs) were identified within this site:

IGE I – loose soil of low water saturation (tQIV);

IGE II – cobble soil of low water saturation (edQIII-IV);

IGE III – sandstone of low strength (marl) (J3kb);

IGE IV – very dense, emolliate sandstone of medium strength (J3kb);

IGE V – very dense, emolliate, sandstone of high strength (J3kb).

As for this site, specific soils are represented by eluvial and industrial formations as well as by upland soils. Slope gravity processes, namely downfall, landslides and screes are not marked here.

By seismic properties this soil is referred to category II.

The estimated seismicity of the construction site is 8 points on the General Seismic Zoning map of 2015.

The groundwater of the Jurassic sediments of mixed origin (natural and man-trigged) were encountered on this site at the depth of 5.1 - 8.5 m, which corresponds to the absolute elevations of 831.33 - 839.3 meters. According to the chemical composition of water, hydrocarbonate, sodium-calcium with the total mineralization of 232.7 - 264.8 mg / l, are slightly aggressive to the concrete of normal density and water permeability of grade W4, in terms of free carbon dioxide and hydrogen (pH). The groundwater corrosive activity in relation to the aluminum sheath of the cable is medium and to the lead sheath of the cable is quite low. This water is slightly aggressive to the reinforcement of concrete structures when periodically wetted.

2 Constructional solution for strengthening the foundation

The structure reconstructed is a tank for drinking water with the maximum product temperature not more than 20°C. The tank itself is a vertical steel cylinder with the capacity of 1,000 metres³. It's wall is 11,920 metres high (eight belts) manufactured and assembled by the method of the roll assembly. The bottom of the tank is also made with the roll assembly of two parts where there is also a slope from the center to the wall. The lifetime of the tank is 25 years provided that the external and internal surfaces of the casing are protected against external and internal media by anticorrosion protection. The main operational characteristics of the tank are indicated in the general drawing (Fig. 1).

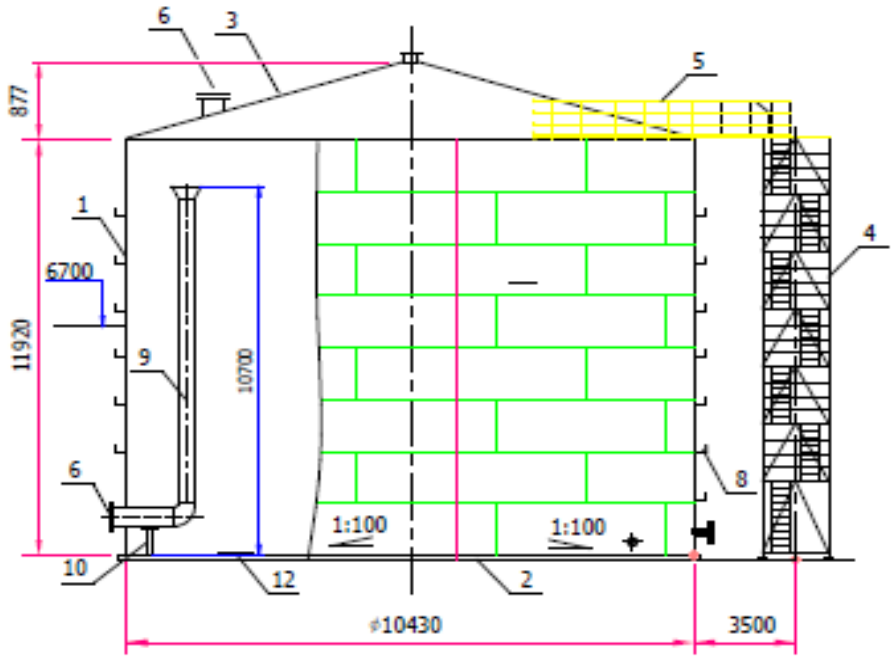

Fig. 1. Geometrical dimensions of the tank reconstructed.

The foundation of the construction is made of circular reinforced concrete with a solid reinforced concrete slab in the central part. When examining the foundations for cracks and deformations, any signs of overstated loads were not revealed, so the condition of the waterproofing layer is to be satisfactory. Table 1 gives the necessary data for determining such physical and strength properties of the foundation as density, propagation velocities of elastic longitudinal, transverse waves, and tensile strength for uniaxial compression.

Table 1. The Structure of the Foundation under Investigation.

The interval in centimeters		Layer Description	Notes
from	to		
1	2	3	4
Well No.1			
0,0	9,0	Asphalt	
9,0	41.0	Concrete	Monolithic samples of concrete selected are No.1-1, 1-2, 1-3
41,0	-	Sand and crushed stone	
Well No.2			
0,0	13,0	Asphalt	

13,0	42,0	Concrete	Monolithic samples of concrete selected are No. 2-1, 2-2, 2-3
42,0	-	Sand and crushed stone	
Well No.3			
0,0	11,0	Asphalt	
11,0	46,0	Concrete	Monolithic samples of concrete selected are No. 3-1, 3-2, 3-3,3-4
46,0	-	Sand and crushed stone	

The overall technical condition of the foundation according to their external signs at the time of inspection is assessed as "up state". The structures physical wear in accordance with Departmental Building Codes 53-86 is not more than 20%.

2.1 Strength characteristics of concrete foundations

The results of concrete sample tests obtained by drilling those samples from the concrete foundation of the structure showed that according to the State Standard 26633-2015 named "Concrete is heavy and fine-grained. Technical specifications." the concrete foundation under investigation has the density of 1.78-1.82 g / cm3 in compressive strength. It can be referred to the concrete of class B7.5 that corresponds to the grade of strength M100 as well.

The concrete strength of the structure under investigation determined by the impact pulse method corresponds to grade B10 of strength grade M100 according to the State Standard 26633-2015 named "Concretes heavy and fine-grained. Technical specifications" [4].

2.2 The parameters of the foundation reinforcement

There is no any reinforcement of the concrete foundation investigated.

The results of the research: While calculating the project [5], special attention was paid to the assessment of the seismic stability of the tank because of the specific conditions of the construction area. The calculation of the foundation carrying capacity was carried out on the basis of the requirements of Set of Rules 50-101-2004 named "The Design and Installation of Foundations and Basements of Buildings and Structures" [6], section 5.6. In accordance with Sec. 5 of Set of Rules 14.13330.2014 named "Construction in Seismic Areas" (adopted in Building Regulations II-7-81 "Construction in Seismic Areas" (Set of Rules 14.13330.2011)) (with Change No. 1) [7] the calculation of structures and foundations of buildings and structures designed for construction in seismic regions should be performed for the main and special combinations of loads, taking into account the seismic load designed.

Thus, the calculation of the foundation for the first group of limiting states was carried out for the following combinations of loads:

constant - the tank's own weight and the weight of the stationary equipment;

long-term - the pressure of liquid and the weight of the stationary equipment;

short-term - snow and wind loads;

special - seismic impacts and impacts caused by deformations of the base caused by a radical change in the structure of the soil.

The values of the normative and design loads on the foundation are shown in table 2.

The calculated hydrostatic pressure of the liquid, kN / m2, was determined by formula 1:

$$q_\omega = \gamma f_\omega \cdot \gamma_\omega \cdot H_\omega \quad (1)$$

γf_ω- the safety factor for the load from water is assumed to be 1.1;

γ_ω - specific weight of liquid, kN / m3; for water 10 kN / m3;

H_ω- water head above the calculated level in metres.

Taking into account all the effective index marks as well as the responsibility and designation of the structure [6, Table. 3], the seismic load Sik, kN, acting on the construction of weighing Qk, related to the point K was determined by the formula 2:

$$S_{ik} = k_1 \cdot k_2 \cdot k_w \cdot Q_k \cdot A \cdot \beta_i \cdot \eta_{ik} \quad (2)$$

Table 2. Normative and Calculated Loads on the Foundation.

Names	Rated load, kgf / m2	Y_f	Estimated load, kgf / m2
1	2	3	4
Constant			
Tank weight	498,3	1,1	548,1
Thermal insulation material	1,56	1,2	1,87
Active vertical and lateral ground pressure	0		
Total:			549,97
Prolonged			
Hydrostatic fluid pressure	x	1,1	x
Total:			x
Temporary			
Snow	240	1,6	384
Wind	73	1,2	87,6
Total:			471,6
Special			
Seismic impacts	77820,53	1,5	116730,8

In order to define if the tank is suitable for further operation or it is necessary to strengthen or repair it, the foundation was calculated on the carrying capacity for the first group of limit states – its strength considering the deformed state.

Loads calculated at the level of the planned ground mark per 1 meter of the foundation length:

The calculated loads of the first group of limit states are constant

$$N = \frac{549,97}{65,5} = 8,39 \text{ kgf} = 0,084 \text{ kN}$$

temporary long-term

temporary short-term

$$\text{N} = \frac{471,6}{65,5} = 7,19 \text{ kgf} = 0,072\text{kN}$$

The total load considering all combinations and reliability factors according to the purpose of the construction, τn = 1,2 (the Ist class of construction responsibility) and coupling

index marks for long-term loads φ1 = 0.95, short-term φ2 = 0.9 for the strength of concrete will be

$$N = 1{,}2(0{,}9 \cdot 5{,}39 + 0{,}8 \cdot \mathrm{X} + 0{,}5 \cdot 4{,}62 + 1144{,}74) = 1527{,}5\ \mathrm{kN}$$

Thus, the long-term load corresponding to the hydrostatic pressure of the liquid will be 73.24 m and the calculated water pressure above the foundation level is 7.31 m.

The calculation according to the second group of limit states (by formation and opening of cracks) was not made because the width of crack opening does not exceed admissible values [7].

To calculate the index marks of load combinations the following data were used:

Types of loads	Index value
Constant	0,9
Temporary long-term	0,8
Short-term (floor structures and coverings)	0,5

The loads corresponding to seismic impacts of this area were considered as sign-variable loads. Wind loads during the calculation were not taken into account.

3 Conclusion

As a result of investigation, it was obtained that the carrying capacity of the existing foundation is slightly lower than it is required for the tank projected. Therefore, it was concluded that the possibility of further tank exploitation is questionable and a deeper study of the current state of foundation and basement concrete substrates is absolutely necessary.

References

1. Federal law No. 384-FZ (2013)
2. Russian State Standard R 54257-2010, http://gostrf.com/normadata/1/4293806/4293806775.pdf
3. Guidance document: 23.020.00-KTN-279-07 (2007) http://www.infosait.ru/norma_doc/54/54769/index.htm
4. Russian State Standard No. 26633-2015, http://www.rags.ru/gosts/gost/61847/
5. L.P. Imaeva, V.S. Imaev, O.P Smekalin, *Card of seismotectonics of Eastern Siberia: monograph* (Izd-vo Tehnicheskogo instituta (f) SVFU, Nerjungri, 2015)
6. Set of rules 50-101-2004, http://docs.cntd.ru/document/1200038307
7. Set of regulations for design and construction: JV 14.13330.2014, http://docs.cntd.ru/document/1200111003