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DETERMINATION OF THE SEISMIC STRENGTH OF AN OIL PRODUCT STORAGE TANK IN THE PRODUCT-FILLED CONDITION

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Abstract

This article develops technical solutions aimed at reducing the seismic hazard identified in existing storage tanks. Scientific and technical proposals focused on increasing the seismic resistance of the tank are formulated, and constructive strengthening measures are developed based on the results of calculations performed using the LIRA-SOFT 10.12 software package. Based on the obtained results, effective technical solutions are proposed to mitigate seismic effects and enhance the overall safety of the tank.

Keywords: LIRA-SOFT 10.12 software, seismic loads, equivalent stress, stiffening ribs, loads, stiffness parameters, dynamic effects.

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Introduction

Ensuring the seismic resistance and stability of existing storage tanks at oil product production facilities is currently one of the most pressing issues. Scientific research is being conducted to ensure the local stability and enhance the strength of storage tank structures. At the same time, these studies indicate the necessity of improving the stability and strength of metal storage tanks through strengthening with stiffening ribs. The decisions of the President of the Republic of Uzbekistan on seismic safety and their implementation play an important role in ensuring stability in regions of the country characterized by high seismic hazard.

An existing storage tank whose parameters exceed the required values specified in Table 3 of Appendix 3 of SHNQ 2.03.05-23 was selected, and recalculation analyses were carried out in the 100% product-filled condition using the LIRA-SOFT 10.12 software package in order to develop appropriate technical solutions. In the computational analysis, four types of loads were applied to the storage tank structure: the self-weight of the structure, the static pressure of the liquid, as well as dynamic loads acting along the X and Y axes based on accelerograms. In determining seismic loads, preselected accelerograms were used as dynamic actions during the modeling process.

During the calculations, stiffening ribs with various structural arrangements were applied to the tank wall, and the magnitudes of equivalent stresses resulting from the deformations occurring under their influence were determined. These results were compared with the equivalent stress values obtained for the case without stiffening ribs. The analysis showed that the application of stiffening ribs leads to a significant reduction in equivalent stresses, bringing them within the limits of the applicable regulatory requirements [1-3].

Based on the results of the calculations, structural drawings of the selected optimal stiffening rib belts were developed and are presented in Appendix 1.

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Table 1

Technical characteristics of the tank adopted for calculation			
№	Designation	Quantity	Unit of measurement
1	Height	11.92	m
2	Diameter	10.34	m
3	Wall thickness	4	mm
4	Bottom plate	2.9	mm
5	Roof	2.6	mm
6	Transverse stiffening rib	6	mm
7	Volume	1000	m^3
8	Design yield strength of steel, Ry	245	MPa

The analysis is carried out for the following loads:

Load 1 – Static load (self-weight of the structure). This load is considered as a permanent load.

Load 2 – Static load (static pressure of the liquid acting on the tank bottom and walls). This load is considered as a permanent load.

Load 3 – Dynamic load (accelerogram acting in the X-axis direction). This load is considered as a seismic action.

Load 4 – Dynamic load (accelerogram acting in the Y-axis direction). This load is considered as a seismic action.

Material classification

Table 3

T/r	Name	Color	Mechanical properties
2	Steel (C245)		Steel grade: C245 Density: ρ=7.85(t/m^3); Elastic modulus: E=2.1006E+06(kg/cm^2); Shear modulus: G=8.0558E+05(kg/cm^2); Poisson's ratio: v=0.3;

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CHARACTERISTICS OF DYNAMIC LOAD ANALYSIS

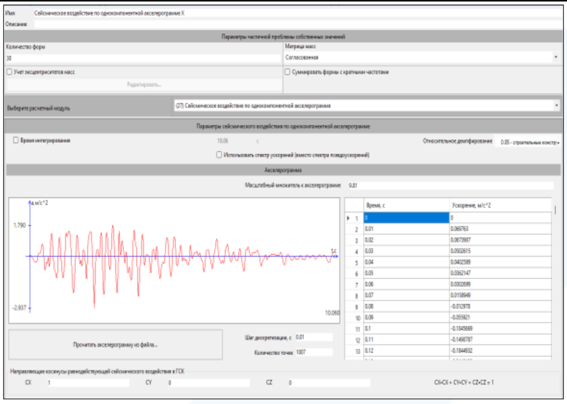	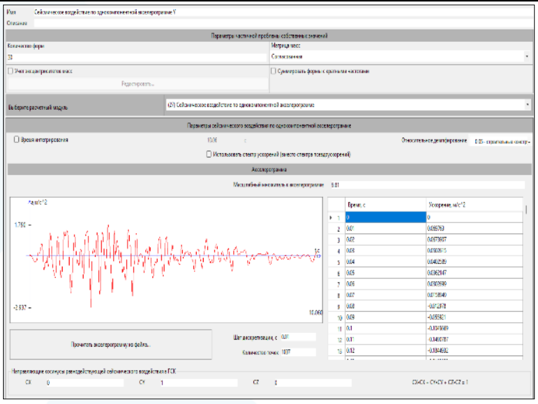
Figure 1a. Dynamic action in the X-axis direction	Figure 1b. Dynamic action in the Y-axis direction

The storage tank considered in this study is a vertical cylindrical metal structure intended for the storage of oil products, and its geometric and structural parameters were adopted in accordance with the initial technical documentation. The tank shell is made of welded steel plates, with a height (H) of **11.92 m** and an internal diameter of **10.34 m**. The shell wall thickness is **4 mm** over the entire height, while the bottom plate and the roof are made of steel with thicknesses of **2.9 mm** and **2.6 mm**, respectively.

To enhance the strength of the tank wall, **transverse stiffening ribs with a thickness of 6 mm** were installed. These ribs reduce the stresses induced in the tank wall by seismic loads and improve the overall stability of the structure (Figures **2a–2d**).

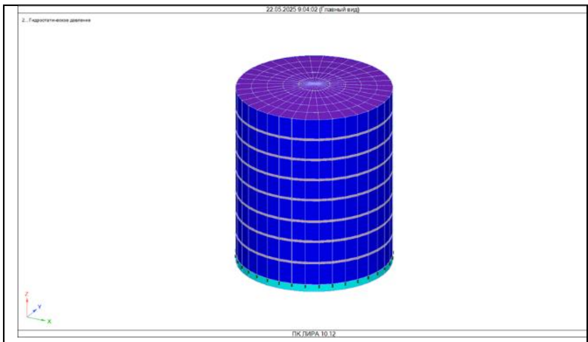	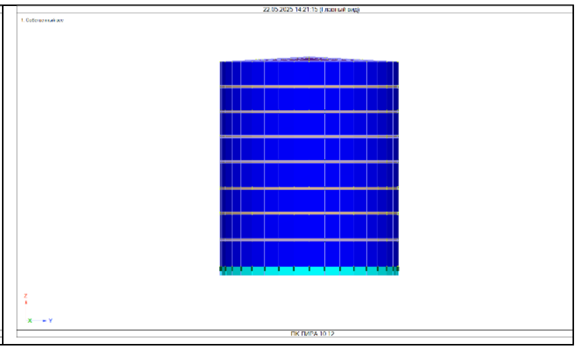

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Figure 2a. General view of the computational model of the tank	Figure 2b. General view of the computational model of the tank
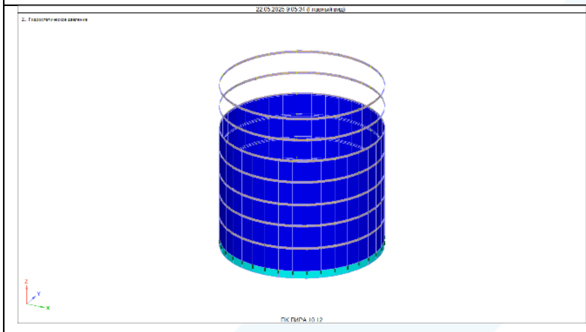	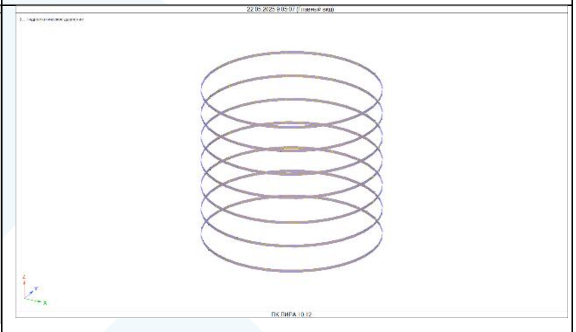
Figure 2c. General view of the stiffening ribs in the computational model of the tank	Figure 2d. General view of the stiffening ribs in the computational model of the tank

For the considered vertical cylindrical steel storage tank, the distribution of equivalent stresses (σ_E) developing in the wall plates was analyzed under various operating conditions, namely when the tank was filled with liquid to 50%, 75%, and 100% of its volume. The calculation results showed a significant variation in stress levels across the lower, middle, and upper zones of the tank wall height.

Different liquid filling levels directly influence the hydrostatic and hydrodynamic pressures developed in the tank shell. Specifically, at a 50% filling level, equivalent stresses are mainly concentrated in the middle region of the tank wall, whereas at 75%, and especially at 100% filling, the stresses reach their maximum values in the lower zone. This behavior is explained by the linear increase of hydrostatic pressure along the height and by the oscillation of the impulsive component of the liquid together with the tank wall during seismic action.

The application of various calculation methods for cylindrical storage tanks, including numerical modeling based on LIRA-SOFT as well as analytical models, made it possible to conduct an in-depth analysis of the actual structural behavior of elements under loading. As a result of using these approaches, the local deformations of the wall shell, the strengthening role of stiffening ribs, the stress

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transfer between the bottom and the wall, and the effects of additional dynamic pressures acting on the structure during seismic loading were comprehensively investigated [4-6].

The calculation results of the storage tank structure are presented in full and are comprehensively illustrated in the "Evaluation Graph of the Limit State of the Tank Structure." This graph visually demonstrates the distribution of stresses along the height, the locations of maximum σ_E values, the effectiveness of stiffening ribs, and the degree to which the structure approaches its limit state. Such studies are of significant practical importance for determining seismic safety measures for storage tank structures.

CALCULATION RESULTS OF THE TANK STRUCTURE

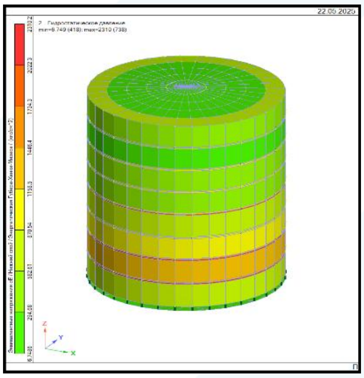


Figure 3a. Equivalent stress σ_E in the lower zone [Hydrostatic pressure], kgf/cm² (100% liquid-filled condition)

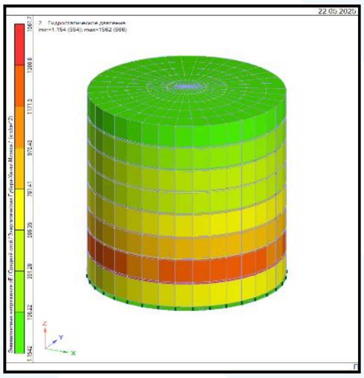
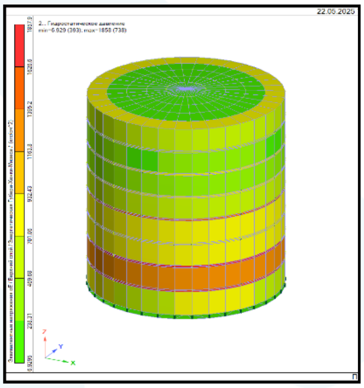


Figure 3b. Equivalent stress σ_E in the middle zone [Hydrostatic pressure], kgf/cm² (100% liquid-filled condition)



igure 3c. Equivalent stress σ_E in the upper zone [Hydrostatic pressure], kgf/cm² (100% liquid-filled condition)

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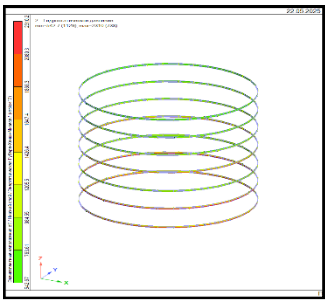

Figure 3d. Equivalent stress σ_E in the lower zone [Hydrostatic pressure] for the strengthened tank belts, kgf/cm²

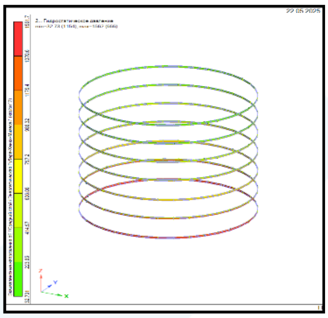

Figure 3e. Equivalent stress σ_E in the lower zone [Hydrostatic pressure] for the strengthened tank belts, kgf/cm²

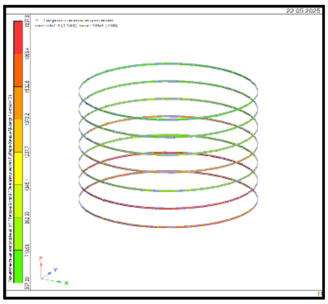

Figure 3f. Equivalent stress σ_E in the lower zone [Hydrostatic pressure] for the strengthened tank belts, kgf/cm²

LIMIT STATE ASSESSMENT OF THE TANK STRUCTURE

Table 4

Analysis of the calculation results of the tank structure				
Liquid filling level	100%	in the walls	in the belts	Ry
Lower layer	σ_E	2310.2	2310.2	2450
Middle layer	σ_E	1561.7	1561.7	2450
Upper layer	σ_E	1857.9	1857.9	2450

Evaluation Graph of the Limit State of the Tank Structure

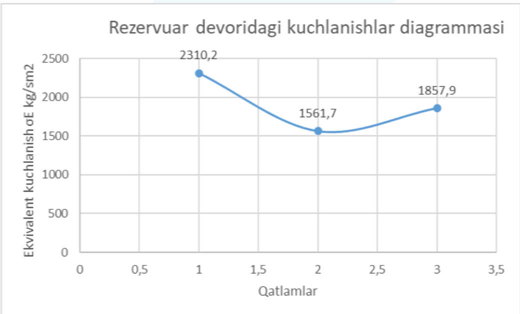

Figure 4a. Stress distribution diagram in the tank wall

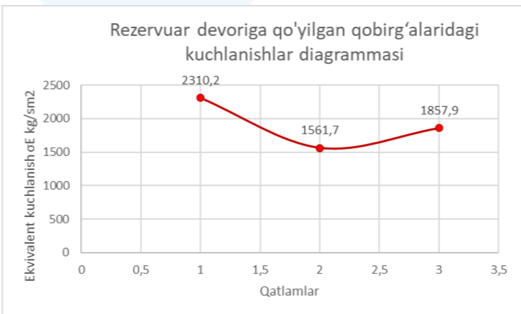

Figure 4b. Stress distribution diagram in the stiffening ribs installed on the tank wall

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Conclusion

As stipulated in Clause 12.4 of Resolution No. PQ-161, technical studies were carried out on a vertical steel storage tank with capacity No. 38 located at the territory of "Farg'ona Neft Bazasi" LLC, with the aim of developing technical solutions to reduce the seismic risk identified in existing tanks. Preliminary inspections were conducted within the framework of implementing Clause 12.3 of Resolution No. PQ-161, and it was determined that the equivalent stress values of this tank exceed the permissible limits specified in the current regulatory documents, namely SHNQ 2.02.01-19 "Foundations of Buildings and Structures" and SHNQ 2.03.05-23 "Steel Structures. Design Requirements.".

As a result, based on Clause 12.4 of the Resolution, it was deemed necessary to develop a scientific and technical solution aimed at improving the seismic resistance of the given storage tank. In the process of developing this technical solution, recalculation analyses were performed using the LIRA-SOFT 10.12 software package. Based on the recalculation results, measures were proposed to enhance the strength of the tank wall by installing a total of seven transverse stiffening ribs made of steel plates, arranged at 1.5 m intervals along the height of the tank (as presented in Appendix 1).

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