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Analysis of the economic efficiency of major repairs of the tank foundation by the displacement method

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Abstract. The article features the application of a method of displacement during major repairs of vertical steel tank bases. Premises on the effectiveness of the application of the displacement method for repairing the bases of vertical steel tanks in comparison with the traditional method of repair are put forward. The comparative characteristics of the displacement method and the traditional method of major repairs of the bases of vertical steel tanks are given. The authors proposed a method of temporary displacement of vertical steel tanks, which is new for Russian practice of major repairs. An algorithm for calculating the cost-effectiveness of repairing the bases of VSTs is developed both by the traditional method and by the displacement method proposed by the authors. Technical solutions are substantiated considering calculating the stress-strain state of tank structures under nonaxisymmetric loading. A model is formed and basic parameters of the economic efficiency evaluation of major repairs of the vertical steel tank base are determined. Evaluation of the economic efficiency of major repair procedures and further maintenance of the repaired tank bases is carried out. A high economic efficiency of the new technological method of displacement is proved in comparison with the traditional method.

1 Introduction

Many foreign companies have technologies that allow constructing cylindrical steel tanks (Figure 1) that can be moved at various stages of operation. In Russian practice, such technologies are not available, since the infrastructure allows oil to be transported to the consumer without moving the tanks. Due to the geographical location of the places where new oil fields are being developed with the presence of frozen water-saturated soils, the problem of repairing the bottoms of tanks often arises. Russian and foreign engineers

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encountered a lot of cases of negative impact of frozen soils on the infrastructure facilities of the main transport.

For example, during the operation of the Trans-Alaska oil pipeline in the USA, a large number of unsolved geotechnical problems arose. When thawing, silty water-saturated permafrost soils from the solid state become liquefied, spreading under the action of their own weight. The thawing of frozen soil, depending on the amount of ice, causes subsidence or complete creeping of dikes. In this case, both uneven subsidence and expulsion of structural elements by frost heaving are observed [1-4].

Fig. 1. Vertical cylindrical steel oil storage tank.

In such engineering-geological conditions, the ESPO and Zapolyarye-Purpe-Samotlor oil pipelines were designed and built. Since the 70s of the last century, fundamental scientific developments related to the problems of frozen soils have been rather slow, although many questions arose long ago. Weak water-saturated, as well as frozen soils make us seriously think about methods of repairing the bases of VSTs. At the same time, why not take advantage of the idea to raise the tank, and after repairing the base, move it to its original place? There are a number of difficulties associated with the fact that during the design it was not possible to raise the VST, and stresses arising when raising tanks of existing standard sizes exceed the permissible limits. To prevent the appearance of unacceptable stresses in the metal structures of the tank during lifting, it is proposed to install a reinforcing frame of a special configuration (Figure 2). However, there is no normative and technical documentation that would clearly regulate the requirements for such a frame [5, 6, 7]. With the advent of numerical methods, it became possible to carry out studies of non-axisymmetric cases of tank deformation. This allowed calculating with a high accuracy the overall stress-strain state of the tank during lifting operations. Solutions of such problems are discussed in [8, 9, 10, 11, 12, 13, 14, 15, 16].

In the Russian Federation, there are a significant number of storage depots of oil products, oil pumping stations, linear production and dispatching stations with the existing problem of repairing tank bottoms [17-18].

The total market value reaches several hundred million rubles. Considering the accumulated foreign experience, repair of vertical steel tank bases by the displacement method can become an effective competitive technology in comparison with traditional methods of repairing bases. Let us consider the main advantages and disadvantages of the methods studied.The displacement method has the following advantages: a guarantee of ensuring the strength and stability conditions of the VST wall; a tank is installed on a completely restored base. The drawbacks of this method include: the need for a crane of high load capacity (up to 120 tons), as well as the difficulty in numerical calculations and installation of the reinforcing frame.

Fig. 2. A reinforcing frame of a special configuration for lifting the vertical steel oil storage tank.

The advantages of the traditional method include: extensive work experience and absence of the need for complex finite element calculations. The drawbacks are a high probability of unacceptable subsidence and deformations of the wall during subsequent operation and a relatively high cost of work.

2 Methods

To assess the feasibility of applying a new method for repairing tank bottoms in Russia, the authors carried out a comparative analysis of the effectiveness of the traditional method and the displacement method of major repairs. The main cost item, logically, is the cost of materials, as well as the costs of buying and renting the necessary machinery and equipment and paying salaries to the repair team. The displacement method involves additional costs for preparing a temporary base with a compacted sand bed, installing reinforcing steel structures, renting a crane with increased load capacity. However, the use of the new technology by dozens of times reduces the cost of subsequent maintenance of the repaired bases of VSTs.

When calculating the economic efficiency of major repairs of the vertical steel tank bases (Table 1, Table 2), the following parameters are identified:

— the period of repair of the VST base and the subsequent eight-year period of its maintenance are considered;

— the average annual revenue from the operation of the tank, net of current costs, is 70 million rubles;

— calculation step - 1 year;

— the discount rate is 14% with a 100% share of own funds [19-21].

3 Results and discussion

The analysis shows that costs related directly to repairing the bases of vertical steel tanks by the displacement method are 1.5 million rubles or 7.3% higher than similar costs when repairing using the traditional method. The effect of using the displacement method is fully manifested in the medium and long term, as demonstrated by Figure 3.

So, the new method, in comparison with the traditional one, pays off in 3.5 years from the moment of carrying out the repair work. The total amount of expenses for the 9 years under consideration when using the displacement method without discounting is reduced by 32%, with discounting - by 16% (from 25.8 million rubles to 22.3 million rubles).

Table 1. Comparative analysis of the payback of major repairs of vertical steel tank bases by the displacement method and the traditional method.

Indicator	2018	2019	2020	2021	2022	2023	2024	2025	2026	Total
Cash flows for repair of the VST base										
Expenses for repair, million rubles										
Displacement method	22	-	-	-	-	-	-	-	-	22
Traditional method	20.5	-	-	-	-	-	-	-	-	20.5
Expenses for VST maintenance, thousand rubles										
Displacement method	-	60	60	60	60	60	60	60	60	480
Traditional method	-	60	100	4400	60	100	4400	60	100	9280
Cash flows as a result of VST operation, million rubles										
Operating cash flow	70	70	70	70	70	70	70	70	70	630
Total net cash flow, million rubles										
Displacement method	48	69.9	69.9	69.94	69.94	69.94	69.94	69.94	69.94	607.52
Traditional method	49.5	69.9	69.9	65.6	69.9	69.9	65.6	69.94	69.9	600.22
Discount rate, %	14									
Discount coefficient	1.00	0.88	0.77	0.67	0.59	0.52	0.46	0.40	0.35	
Cash flow with discounting, thousand rubles										
Displacement method	48	61.4	53.8	47.2	41.41	36.3	31.86	27.95	24.51	372.44
Traditional method	49.5	61.4	53.8	44.28	41.41	36.3	29.8	27.95	24.5	368.97

Table 2. Indicators of the efficiency of major repairs of vertical steel tanks bases by the displacement method and the traditional method.

Displacement method	**Traditional method**
Profitability index	
17.7	15.3
NPV (net present value), thousand rubles	
372442	368970
Payback period with discounting, days	
116	116

Analyzing the efficiency indicators of using the considered methods of major repairs of the bases of VSTs, given in Table 2, we can, first, note the total savings of discounted costs for the maintenance of the bases, considering the initial repair costs of about 3.5 million rubles, and second, a half-month reduction in the payback period of major repairs.

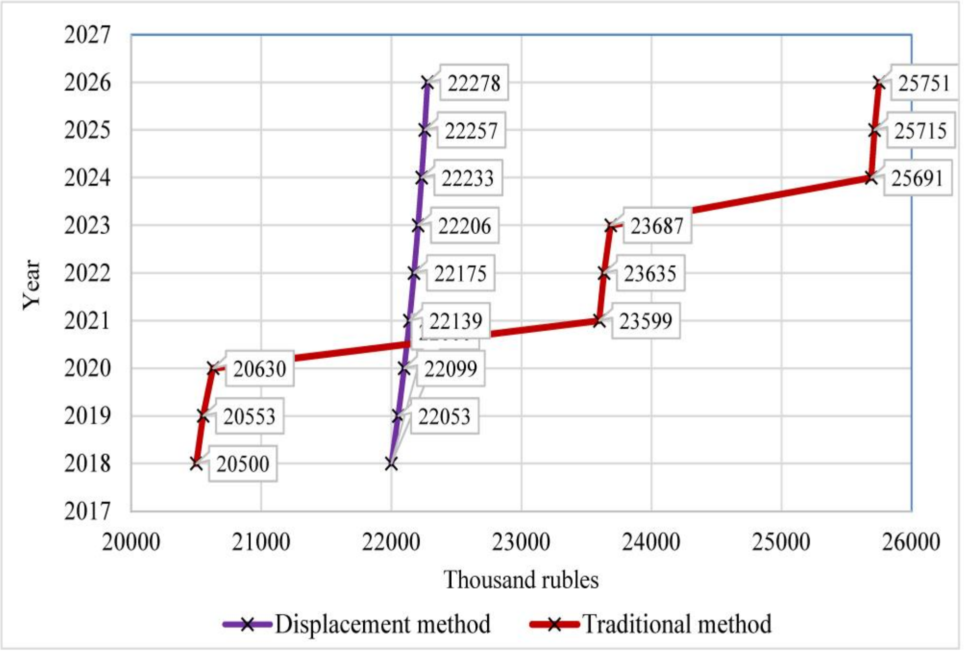

Fig. 3. Discounted amount of costs for repairs and subsequent maintenance of vertical steel tank bases.

Conclusions

In this paper, the authors proposed a method of temporary displacement of vertical steel tanks, which is new for Russian practice of major repairs. An algorithm for calculating the cost-effectiveness of repairing the bases of VSTs is developed both by the traditional method and by the displacement method proposed by the authors.

Using the new technological approach allows reducing the total costs without adjusting for the discount rate by 32%, and with the discount - by 16%. The effectiveness of the application of the displacement method in comparison with the traditional one is evident in the medium and long term, which is associated with a significant cost saving for the subsequent maintenance of the repaired base.

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