Increasing the Seismic Isolation of Gas Tanks Using Seismic Isolation Systems

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Abstract. Some of the important issues of the modern world are associated with energy resources, namely, the search for new sources, energy conversion, use and storage of such resources. The consumption of fuel energy resources is not only the foundation for the development of basic industries, but also an essential part of human life. Every year, the use of such fossil resources increases, so there is a need for long-term storage of fuel. Gasholders are used for storing gas fuel, which allow not only to store resources for a long time, but also to provide the consumer with the necessary amount of fuel. The construction of these structures can cover various areas, including areas with special construction conditions, in particular, those prone to seismic activity. Ensuring seismic protection of gasholders not only allows the safety of fuel, but also prevents environmental disasters associated with fuel spills.

1. Introduction

One of the most common energy resources is natural gas. Gas production in Russia in 2018 amounted to 733 billion m³, which is the second largest indicator among all countries of the world [1]. Gas is used in many industries, including the chemical and metallurgical industries, and gas is also consumed in public utilities and as fuel for transport. Natural gas has several advantages over other fossil fuels. Gas emits less carbon dioxide into the atmosphere for the same amount of energy generated as coal or oil. Also, gas fuel is liquefied easier and more efficiently than coal and oil. When liquefied, natural gas is reduced in volume 600 times. Therefore, the production and purchase of liquefied natural gas (LNG) in recent years has become widespread in many countries around the world.

In Russia, the largest gas liquefaction plant is located on Sakhalin Island [2]. According to the seismic zoning maps, the seismicity of this region is 8-10 points [3].

For LNG storage, special engineering structures are used - gasholders. These objects are widely used in the energy construction of many countries of the world, the most widespread in Japan, South Korea and China, also in Europe (Great Britain, Spain, Greece) and the countries of North and South America (USA, Mexico) and Australia [4]. A large number of reservoirs for the oil and gas industry are designed and built in special construction conditions, including seismically dangerous areas. Therefore, to date, a large number of theoretical studies have been accumulated on the design of...
reservoirs in regions with high seismic activity [5-14]. Figures 1-2 show some studies of foreign scientists dealing with the design of LNG gasholders.

![Figure 1](image1.png)

**Figure 1.** Deformation of the external protective tank of LNG under the action of seismic load [5].

![Figure 2](image2.png)

**Figure 2.** The result of seismic analysis, including the external reservoir, internal structures and fluid [6].

Existing foreign theoretical research in the field of gasholder design shows that the use of seismic isolation systems is effective in earthquakes. But despite the extensive experience in the construction of reservoirs, we can not say that all issues have been fully investigated, the evidence is damage to gasholders [15-19]. Such damage can cause significant environmental damage, comparable to the accident that occurred in the city of Norilsk on may 29, 2020.

The article presents theoretical studies of the seismic resistance of a gasholder intended for storing LNG under various soil conditions using seismic isolation systems.

2. Methods

To assess the seismic stability of a closed-type gasholder for LNG storage, data on the seismicity of the southern part of Sakhalin island were used. Rubber-metal supports are used as seismic isolation elements.

The gasholder is made of monolithic reinforced concrete and has a cylindrical shape with a height of 48 m, in plan it has a circular outline with a diameter of 86 m.

3 models of the gasholder were considered. The first version of the model is shown in figure 3, which shows the reservoir without the use of special means of seismic isolation. In this model, the bottom of the tank is the Foundation.
The second and third options (Fig. 4) have an additional slab foundation with uprights, on which seismic-insulating rubber-metal supports will subsequently be installed.

The main objective of the study was to assess the impact of using seismic isolation of a gasholder, taking into account various characteristics of soil foundations. The considered soils were sandy, clayey and coarse-grained soils. The soil characteristics were taken in accordance with the standard values presented in [20, 21]. Table 1 summarizes the soil parameters for the three models.

| Soil     | Deformation modulus, T/m² | Poisson's ratio | C₁, T/m³ | C₂, T/m |
|----------|---------------------------|-----------------|----------|---------|
| Sand     | 1100                      | 0,3             | 74,04    | 2820,51 |
| Clay     | 2800                      | 0,38            | 262,0    | 6763,29 |
| Coarse soil | 5000                     | 0,27            | 312,3    | 13123,36 |
The calculation was carried out in the SCAD 21.1 program according to the linear spectral technique, which assumes an estimate of the seismic load presented in [3]. The calculation took into account the loads from gas fuel, the weight of the structures, as well as snow and wind loads. All three soil conditions were considered for each model.

3. Results
Some results are presented in Tables 2-4, where maximum internal stresses were compared. The results given in the tables show how the internal stresses of structural elements on different soils change with the introduction of seismic isolation.

Table 2. Values of deformations of models without seismic isolation on the ground.

| Comparative values | Sand     | Clay     | Coarse soil |
|--------------------|----------|----------|-------------|
| Maximum stress, T/m² | +Nx   | 4345.06  | 4089.59     | 3600.46 |
|                     | +Ny   | 3993.28  | 3738.86     | 3448.8  |
|                     | -Nx   | -4703.22 | -4298.86    | -4070.53|
|                     | -Ny   | -4492.57 | -4072.64    | -3886.06|

Table 3. Values of deformations of models without seismic isolation on racks.

| Comparative values | Sand     | Clay     | Coarse soil |
|--------------------|----------|----------|-------------|
| Maximum stress, T/m² | +Nx   | 1954.46  | 2726        | 2849.06  |
|                     | +Ny   | 1268.52  | 1754.18     | 1786.03  |
|                     | -Nx   | -2517.61 | -3909.81    | -4180.1  |
|                     | -Ny   | -1442.27 | -1670.38    | -1706.01|

Table 4. Values of deformations of models with seismic isolation.

| Comparative values | Sand     | Clay     | Coarse soil |
|--------------------|----------|----------|-------------|
| Maximum stress, T/m² | +Nx   | 1932.44  | 1825.42     | 1751.37  |
|                     | +Ny   | 1822.75  | 1899.2      | 1878.94  |
|                     | -Nx   | -2160.11 | -2010.24    | -1941.59 |
|                     | -Ny   | -2072.78 | -2153.27    | -2130.41 |

4. Conclusions
1. In the absence of seismic isolation, the effect of the property of the soil condition turns out to be significant, the stress state decreases with an increase in the rigidity of the soil base.
2. With the introduction of an additional Foundation, the influence of the soil changes, i.e. with increasing soil stiffness, the stress state of the gas tank structure increases.
3. When using seismic supports, the soil has less impact on the structure. Due to the introduction of seismic-insulating supports, structural elements are reduced by about 2 times, which makes it possible to increase the efficiency of using rubber-metal supports.

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