TECHNOLOGY OF WASTE DISPOSAL OF THE OIL AND GAS COMPLEX

Zotsenko M.L.
Doctor of Technical Sciences, Professor, Professor
of the Department of Building Technology
Poltava National Technical Yuriy Kondratyuk University, Ukraine

Mykhailovska O.V.
Ph.D., Senior Researcher, Associate Professor
of the Department of Building Technology
Poltava National Technical Yuriy Kondratyuk University, Ukraine

Abstract. The article proposes technological solution of sludge storage with vertical anti-filtration wall of soil-cement. It is proposed to produce soil-cement elements by blending technology without removing the soil in the type of "wall in soil". After hardening of soil-cement elements along the perimeter of the waste, up to 60% of the soil mass is recessed. The choice of technology of soil-cement elements is made in accordance with the feasibility study. The dimensions of the soil-cement elements and the dimensions of the bottom waterproofing are determined at the design stage. The dimensions of the soil-cement elements depend on the particular site of construction, taking into account the soil category, the depth of groundwater. After filling the waste deposit, it is recommended to arrange the soil-cement coating. The coatings are laid on a drilling mud thickened to a rigid-plastic consistency with the addition of soil to the construction site. After the soil cement has hardened, the sludge coatings are covered with a layer of soil. The advantages are the low cost of production by using a waterproof soil layer as the bottom of the structure. The optimal humidity of a mixture of drilling mud and soil in the ratio of 60:40 is investigated. The modulus of deformation of the compacted mixture is determined. It is sufficient for laying on the compacted surface of a flooring from a soil cement at arrangement of a sludge deposit.

1. Introduction

Concentrated solutions of acids, inhibitors, surfactants are used in the drilling and operation of wells and for the intensification of extraction of hydrocarbon raw materials. Most often, waste disposal is used to eliminate drilling waste. Waste disposal of the oil and gas industry is carried out in specially designated places, deep underground storage facilities in the territory of works. To prevent the entry into the soil and surface groundwater of toxic drilling waste a precautionary measure is the construction within the drilling site of underground storage which toxic waste is collected. The dimensions of the barns are determined by the project and should correspond to the volume of drilling waste. The conditions of construction of slurry barns and their construction depend on the engineering-geological conditions of the area allocated for the construction of the well and the characteristics of soils of this area [1].

2. Basic investigation

2.1 Overview of known recycling technologies

Important when arranging waste is to provide waterproofing the bottom and walls. For this purpose, filtration screens (concrete, geomembranes [2], materials based on synthetic cloth, etc.) are used [3,4]. However, the screens of these materials are not durable enough and damage to them upon contact with chemicals will result in negative environmental effects.

Kachala T.A. (2019) proposes to use composite material based on synthetic fabric (cloth) modified on both sides by polymer-bitumen binder with high thermoplastic and waterproofing properties in the construction underground storage walls [5].

Fig. 1. General view of the storage of waste [6]

Timofeyeva K.A. (2016) propose a soil-cement waste storage. In this case, use the technology of making soil-cement elements by blending technology without removing the soil [3,4]. Wells are being drilled along the perimeter of the underground storage facility. These wells are filled with soil cement, which is a protective screen against groundwater. Then a pit is dug, the bottom of which is waterproofed by such technology [7]. Also known is the method of fixing the bottom of the pit made of soil cement. Soil-cement which is mixed separately in a concrete mixer and poured with a continuous layer on the bottom [7]. Such storage of drilling waste is arranged open. It has at least 0.5 m height and mineral wire hedges along the perimeter of the mineral soil. This method is time consuming and the main disadvantage of this solution is that the storage is open.

It is also possible to arrange a repository of drilling waste with an anti-filtration veil of the "wall in soil" type. An anti-filtration curtain of the "wall in soil" type of soil-cement elements is immersed in a water-resistant layer of soil. This makes it possible not to arrange an anti-filtration screen of the bottom of the drilling waste storage, the function of which will be performed by a water-resistant layer of soil [4]. This design of the bottom will be more economical. The downside of this design is that the repository is designed to be open. In this case, the possibility of evaporation of harmful substances is not excluded. Thus, there is a need to arrange coverage of the drilling waste storage facility.

Thus, the task is to develop a constructive solution for an efficient, economical and safe storage of drilling waste with a soil cement screen and to arrange its coverage.

2.2. Lifetime waste storage technology

Soil-cement is a mixture of clay soil, cement and water. The main factor in the conversion of soil properties is cement, which is a polydisperse and polymeric system that, after the addition of water, forms a rocky material. Known studies on the effect of aggressive components of drilling waste on soil-cement have shown that over time. The strength of soil cement increases over time (from W4 to W6). This demonstrates the stability of soil cement to aggressive components of drilling waste [7].

Therefore, the authors propose to dig the walls of the pit of the drilling waste storage with a vertical anti-filtration veil of soil cement. The soil-cement elements should be made by blending technology without removing the soil by the «wall-in-soil» type. The walls of the storage deposit into the waterproof layer of soil. The store should be closed.

The choice of technology of soil-cement elements is made in accordance with the feasibility study [7]. The sizes of soil-cement elements and the dimensions of the waterproofing of the bottom are determined at the stage of working design in relation to a specific site of construction, taking into account the soil category, the depth of ground water.

The construction of a lifelong waste storage facility is as follows. For the perimeter of the planned sludge storage, a monolithic vertical anti-filtration wall of the type "wall in soil" is constructed of soil cement elements (Fig. 2). The distance between the centers of adjacent elements should be 0.8d (d - diameter of soil cement elements).

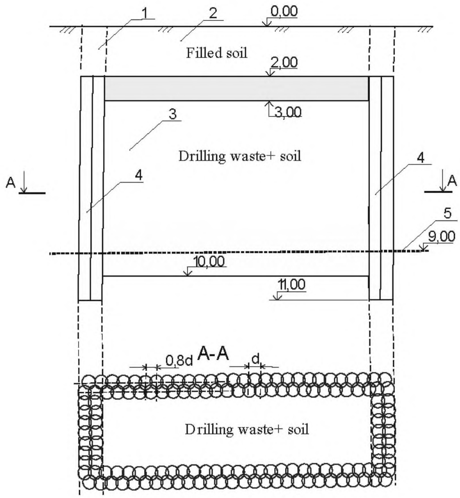

Fig. 2. Drilling waste storage

The soil-cement elements are produced by the blending method. This method is to use the special equipment to loosen the soil without removing it. At the same time a slurry is pumped into the loose soil. The soil-cement mixture is then mixed and compacted.

Thus, we obtain cylindrical soil cement elements with a diameter of 0.3-0.8 m and a length of up to 30 m [3]. The wall-to-soil anti-filtration curtain of soil-cement elements is immersed in a water-resistant layer of soil to a depth of at least 1 m in order to ensure no filtration. An important factor in the design of the repository is the choice of the location of the repository, provided there is a waterproof layer at the optimum depth from the surface (8-20 m).

After hardening of soil-cement elements along the perimeter of the storage, up to 60% of the soil mass is recessed [3]. Filling of life storage with drilling waste is carried out after soil cement hardening.

The period of wetting in the moistened state lasts 28 days. Over time, the strength and water resistance of soil cement increase.

As the storage of the drilling waste is filled, the soil and drilling waste are mixed in the storage to a tight consistency. Stirring is carried out in order to thicken the waste and to arrange the topsoil cover. The soil cement coatings are laid directly on the drilling waste, which is thickened to a tight consistency.

The soil cement is produced at the construction site in a horizontal concrete mixer of continuous action from soil (loam, sandy loam), Portland cement grade M400 in the amount of 20% by weight of dry soil and water. With the help of mortar pump the soil cement is laid on thickened drilling waste with a uniform layer with a thickness of not less than 0.8 m.

The size of the drilling rig and its volume, profile and depth are determined at the design stage. The design of the repository is different for each site of construction, depending on the soil category, depth of groundwater, and other characteristics.

2.3. Investigation of waste mixture parameters

Investigation of soil characteristics and determination of optimum humidity was performed with drilling waste of Yablunovka oil and gas condensate field well No. 355. The drilling mud had a density of 1.49 g/cm^3, sediment volume of 1.5 ml, solids content was 3%, hydrogen pH value. 6.71.

For the research, the loam was refractory from a depth of 2 m. The average humidity of the soil samples was about W=0.2.

According to the results of laboratorys research, it was determined that the drilling mud had an average humidity of soil samples W=0.50. Its humidity at the yield point W_L=0.36, the moisture at the rolling point W_p=0.21 (Table 1).

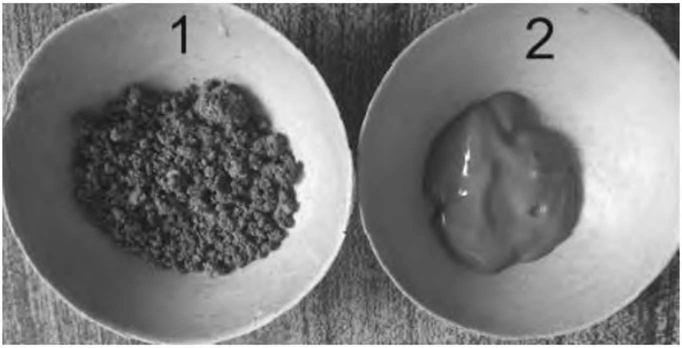

Fig. 3. General view of the components of the mixture: *1* - rigid loam; *2*- drilling mud

It was determined that this drilling mud belongs to the loam of the fluid. The research was performed according to standard laboratory methods of soil research according to DSTU B B.2.1-17: 2009 [8].

Table 1

Indicative characteristics of components of drilling waste mixture and loam loaded at variation coefficient, υ

Objects of research	Moisture, W/υ	Plasticity limit,	The boundary is fluid, W_L/υ	Quantity of plasticity, I_L/υ
Drilling waste	1,01/0,012	0,21/0,06	0,36/0,14	0,15/0,1
Loam	0,20/0,08	0,25/0,07	0,37/0,12	0,12/0,11

The composition of the soil under equal conditions, has a significant impact on the intensity of the compaction process and its final results. An increase in the amount of free, non-sticky water that allows the soil particles to move relative to one another, which results in a decrease in the resistance of the particles to move under external loading. With the same humidity, the amount of free water depends on the composition of the soil.

At constant values of initial soil moisture and specific volume of the soil skeleton, a higher compaction intensity corresponds to soil mixtures having more free water.

The mineral composition of the clay fraction also determines the properties of the soil skeleton when interacting with water. Clay minerals with a mobile crystalline lattice have the greatest surface activity and hydrophilicity, which are capable of holding water not only on the surface but also between the packet space of the crystal lattice. Therefore, with the same percentage content of clay fraction, the highest values of optimum humidity will have soils with montmorillonite foliage component, and ultra-low - kaolinite. The drilling mud has a significant amount of montmorillonite clay component so optimum humidity in this case was 0.25.

The optimum soil moisture can be theoretically determined.

L.D. Bohoslovsky proposes to determine the optimal humidity by the formula

$$W_{opt} = W_p + (0,1 \div 0,3)\,\mathrm{I}_p . \quad (1)$$

$W_{opt.}$ - optimum humidity of the mixture (soil); I_p - plasticity number; $W_{p.}$ - plasticity limit; W_L -strength limit.

According to the experiments conducted by V.I. Krutov, optimal humidity was assumed to be 3% more moisture at the limit of plasticity, according to the instructions of DORNDI $W_{опт} = W_p$.

M.Y. Telegin, CA Hohentogler, E.M. Kupriyanov is also recommended. $W_{опт} = W_p$ V.I. Birulya proposes to determine the optimum humidity depending on the soil yield point: $W_{opt} = 0,62 W_L$ (2)

Research done by O.K. Birulya, N.F. Sasko, A.F. Kotivitsky, aimed to establish the relationship between the optimal humidity standard compaction and the upper boundaries of plasticity of the respective soils with the help of transient coefficients. As a result of data processing on 572 samples of soils of different origin and particle size distribution the formula was obtained

$$W_{opt} = 1,5(0,5W_L - 0.25I_p - 0,01) . \quad (3)$$

The characteristics of the soil mixture were determined under laboratory conditions. The loam was mixed in a state of natural humidity. The average humidity of the soil samples was thus 50%.

The values of the optimum humidity were determined for the ratio of the mixture of drilling mud and loam 60:40. The smallest value of optimum humidity can be obtained by calculations according to the method of O.K. Birulya - 0.25. The values of optimal humidity were obtained according to the formula of Birulya V.I. and according to the method of O.K.Birulya, N.F. Sasko are close and differ in size by up to 3%. The value of optimal humidity determined by V.I. Krutov - 0.41, for L.D. Bohoslovsky - 0.3. The theoretical values of optimal humidity vary over a wide range.

Therefore, for the mixture under consideration, the values of optimal humidity and optimal skeletal density were determined in accordance with the standard soil compaction technique using a stationary mechanized soil compactor MSU-1 (Fig. 4)

The design of the device MSU-1 consists of a base plate and a gearbox, an electric motor, a rack with brackets, the rod on which the weights move. The drive design is made of two pivotally connected rods. This design maintains a constant drop height of the weight in the process of sealing the sample. A variable form is attached to the plate.

For the experiment, 6 samples of the appropriate size were made. Dynamic compaction of the mixture of soil and drilling waste is performed by the following procedure. A certain amount of water is added to the soil sample at initial humidity to obtain samples of optimum humidity. A sample of the soil mixture was applied with a thin layer at the bottom of the tank and moistened evenly with a laboratory burette. With this method, moisture in the soil was distributed evenly. The mixture was thoroughly stirred and poured into a pre-assembled and oiled glass of the instrument MDU-1 (Figure 3) [9,10]. The stirred and moistened mixture was kept in the hydrator for about 2 hours in order to distribute moisture evenly. The mixture was poured into a glass from a height of about 10 cm.

The height was the same for all samples. Prior to sealing, the specimen was compressed for several minutes with a static load of 10 kg. This was done to reduce macro pores and air voids. The initial humidity of the samples was more than half the humidity at the boundary of plasticity. Since the humidity of the samples is less than this value, the sealing of the samples will be less effective. Experiments on dynamic compaction of the samples were carried out at equality of initial height of the samples.

Therefore, before compaction with a depth gauge, the soil level in the glass was checked. After the soil compaction is completed, the mass of the glass with soil is determined to the nearest 1 gram and two samples are taken to determine the humidity. Then a steel beaker

with a prepared soil sample was mounted on the base plate of the device MDU-1. The deformation of the soil in the course of the experiment on the instrument MDU-1 is measured with a depth gauge from the top of the glass after each stroke with the number of strokes up to 10.
The experiment was stopped if the deformation difference during the last 5-10 strokes would be less than 0.5 mm.

The average value of the optimum humidity of the mixture when the ratio of drilling mud to soil 60:40 was 0.27. That is, the closest value to the experimental obtained theoretically using the method of O.K. Birulya, N.F. Sasko.

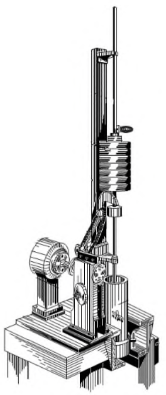

Fig. 4. MDU-1 appliance

Further, samples of the compacted mixture were made according to the ratio of drilling mud and loam 60:40. Next, the compressibility of the mixture in the K-1 compression device was evaluated. According to the results of compression tests, the modulus of deformation at optimum humidity W=0,27 and ρ_d=1,65 g/cm^3 was E=27 MPa. Such considerable compressibility of the mixture is not necessary for the site of disposal of drilling waste. Therefore, it may be considered sufficient to cover the overburden of the cement-based drilling waste on such a compacted basis.

3. Conclusions

1. The aforementioned method of creating a technological solution for the arrangement of a drilling waste storage facility can be used in any territory. An important factor in the design of the repository is the choice of location, provided there is a waterproof layer at the optimum depth from the surface (8 – 20 m).

2. The advantages of the construction of a storage facility with a soil cement coating, which is embedded on a drilling mud thickened to a rigid plastic consistency with the addition of soil to the construction site, is the low cost of production due to the use of a waterproof soil layer as the bottom of the structure. After hardening of the soil

cement, the coverings of the storage are covered with a layer of fertile soil. Thus the solution of the problem of utilization of the soil storage facility extracted during construction is possible.

3. It is proposed to fill the storage of drilling waste with a mixture of drilling mud and ground soil (in the conditions of the Poltava region - loam-tight loam) in the ratio 60:40. At this ratio of the mixture, the modulus of deformation of the mixture was 27 MPa. Which is sufficient to arrange the coating of soil cement storage.

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