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Research paper

Oil and Gas Storage Facilities Construction Operations Standardization

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Abstract

This is the first research that provides the calculation of time and labor standards for foundation works at oil and gas storage facilities construction. A foundation works performance for two identical vertical steel tanks is under investigation. The reinforced soil-cement piles are suggested as the most economical way of foundation works performance at gas and oil storage facilities The deep soil mixing technology is considered. The detailed description of suggested technology is presented along with time spent for each technological element. This paper provides data on the machinery and materials needed for construction. A time study method was applied to compile a working day photo-fixation. The obtained data were processed using the method suggested by engineer Prussak. The nonlinear correlation of drilling time versus depth of reinforced soil cement piles was obtained. The influence of geotechnical conditions on time and labor consumption is presented. Time and labor standards for manufacturing 1 m^3 of soil-cement piles have been calculated.

Keywords: *cement, clay, cost rates, drilling, deep soil mixing technology, geotechnical conditions, loess loam, labor, photo-fixation, reinforced soilcement pile, soil, time, vertical oil tank.*

1. Introduction

The construction of ground structures at oil and gas fields constitutes the essence of its landscaping. The main features of oil and gas industrial construction are the dispersion of industrial facilities, the absence of roads and infrastructure, and, occasionally, complex geotechnical conditions.

The most widespread way to store oil and liquid oil products is in steel stock tanks is vertical or horizontal cylindrical containers with a volume of hundreds of thousands m3. It's an integral part of any petroleum storage depot. The best way of transporting the crude oil and its products is elevated pipeline. There are also miles of under-ground technological pipelines laid underground in protected trenches.

Prior to construction process initiation, specific arrangements should be undertaken to ensure that oil and gas transport and storage facilities are constructed under established deadlines and quality requirements. These issues are addressed by the development of a site work execution program.

This process includes design of cost-estimating documentation and a construction schedule which is impossible without time standards developed for elements of preliminary and main works.

Geotechnical preparation of an oilfield territory is an essential part of the latter. Foundation work is the most labor-consuming, and, therefore, time-consuming one. For that reason, any improvement in the foundation work technology will ultimately lead to refinement of the oilfield site work execution program and saving of time and money of a developer.

The most industrialized and less time-consuming foundation type for an oilfield setting up is a pile foundation [1]. The convenient types of piles for petroleum production and refinery industries are the precast concrete and drilled piles. The former type provides higher material strength but requires transportation efforts while the latter type is being manufactured directly at the oilfield from the transported components. The both types require almost no soil extraction and may have a depth of 5 – 15 m.

The reinforced drilled piles manufactured of soil cement instead of concrete have a set of significant advantages over the mentioned above pile types [2 – 5, 10 – 15]. The manufacturing of reinforced soil-cement piles (RSCP) requires only cement and water. There's no need to transport coarse-grained fraction crucial for concrete piles. This technological benefit has an increased significance in cross-country areas of an oilfield location. The carrying capacity of RSCP is less than that of concrete piles, which in turn provides the unnecessary concrete strength reserves. That disadvantage may be compensated by the soil-cement reinforcement and length of piles which do not require any casing irrespectively of the depth [6-8]. The borehole stability is secured all the construction time because the soil is not being removed from the well.

2. Main Body

2.1. Problem statement

Ukrainian standards do not contain cost rates for manufacturing the RSCP. At the designing stage of oil and gas storage facilities, the lack of data on the time, materials, labor, and machinery needed for manufacturing the RSCP doesn't allow the engineer to correctly utilize it. For that reason, concrete piles are often being used instead of RSCP even though concrete has unjustified high strength reserves that are not being utilized.

This study provides the research data on the technology for manufacturing the RSCP, the number of resources needed, and machinery used. The foundation works for construction of two vertical steel oil tanks in Chernihiv oblast is under investigation (fig. 1)

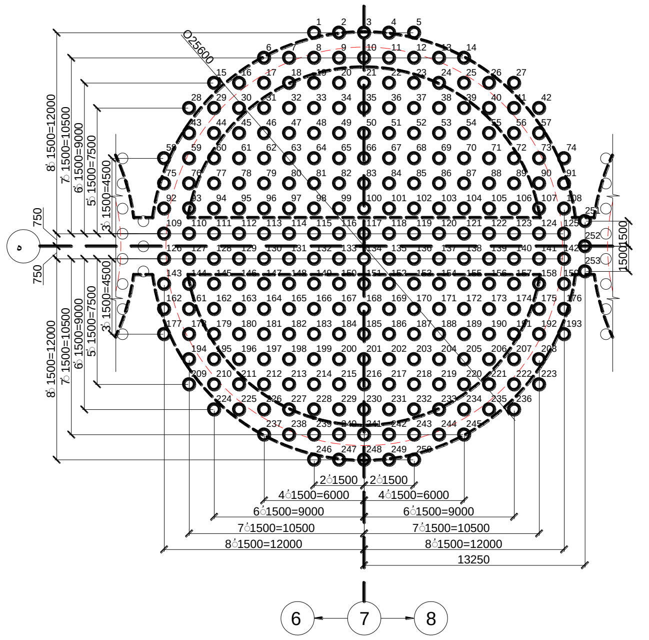

Fig. 1: A layout of reinforced soil-cement piles positioning underneath the vertical steel oil tank

The construction of the tanks is similar but the foundation was of two types: soil-cement elements and reinforced soil-cement piles. The difference is that the former type is not connected to the super-structure (and considered to a ground improvement technique) while the latter is structurally connected with a superstructure.

Soil-cement is a particularly effective material when used for foundation works under the objects that have a large number of loading/unloading cycles. Oil tanks tend to change its actual weight multiple times during its service since the amount of oil inside varies throughout the time.

However, due to the availability of clay as a major component of a mixture, the soil-cement has a high value of elastic compressibility (about 2 ‰) which is close to that of a steel [9]. That means the foundation under the oil tank will not get an additional subsidence or heeling because of a cyclic regime of structure's functioning.

2.2. Technology description

The detailed analysis of the technology used for the performance of foundation works at oil and gas storage facilities construction is a crucial step in designing the cost rates. Under the given circumstance (geotechnical conditions and technical capabilities of a contractor), the deep soil mixing technology (DSM) was adopted. The technology consists of the following:

– the drilling device is dipping to a designed depth without a soil removal;

– the cementing grout is supplied to the bottom of a well simultaneously with its rotation and lifting to the top of a well;

– the soil is mixed with a grout along the borehole 2 – 3 times until its homogeneous state is reached.

The equipment used is shown in fig. 2. The mechanized operations were performed by the drilling machine on automobile chassis BM-811m and a mixing station.

Fig. 2: The drilling machine on automobile chassis BM-811m used for manufacturing reinforced soil-cement piles

From the technological perspective, DSM is a complex mechanized process. It was performed by a group of workers: a drilling operator, mixing station operator, assistant. The procedure DSM technology incorporates the following processes.

Deployment of supports (fig. 3) provides a stationary position for the drilling rig.

Fig. 3: The supports deployment

Deployment of a drilling tower (fig. 4) is a crucial process that directly impacts the position of RSCP which can be vertical or tilted.

Fig. 4: The drilling tower deployment

Drilling operation with a simultaneous cement grout supplying provides the necessary conditions for soil-cement manufacturing (fig. 5). The precise control of cement and water consuming must be carried out on this stage in order to ensure that a finished product (cement stone) will have the designed mechanical properties.

Fig. 5: Drilling process (top) and cement grout supplying (bottom)

Steel bars reinforcement placing provides a higher mechanical strength of soil-cement. It enables applying higher loads to the RSCP and fully realize its carrying capacity by the side surface (fig. 6).

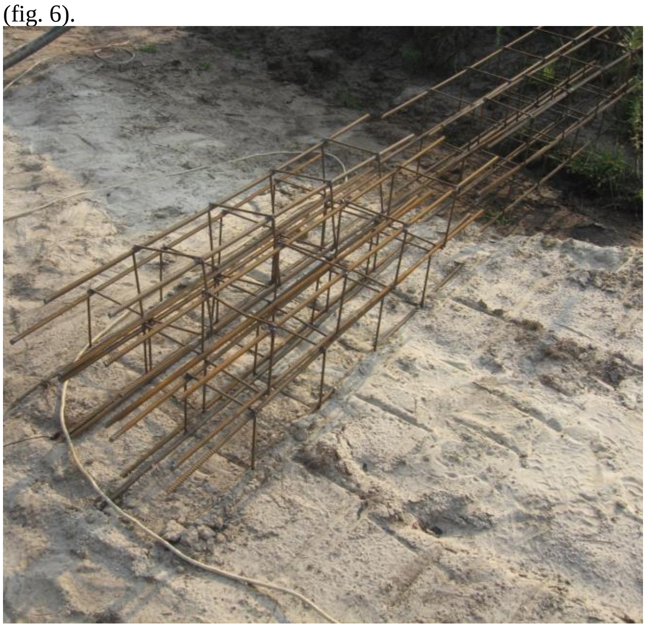

Fig. 6: Reinforcing frame to be dipped into the reinforced soil-cement pile

The last procedure is the relocation of a drilling rig to the next station followed by the next identical cycle (fig. 7).

Fig. 7: Relocation of a drilling rig to the following station

DSM technology has a large number of minor operations that require a comparatively small amount of time. But the extreme number of technological elements complicates the process of its research. Among the minor operations there is supports removal, underlying the supports with wooden boards, soil removal from drilling tool, etc. Time spent on these elements was included in the main procedures listed earlier.

2.3. Data processing.

The method suggested by Prussak [9] was used for field data processing. The essence of a method is that the whole group of workers is being observed and the data is collected in a graphic form. The investigation lasted for 3 shifts. The time spent for each element of work and idle is being recorded in the photo-fixation sheet. during the first shift, there has been manufactured 5 RSCP (fig. 8).

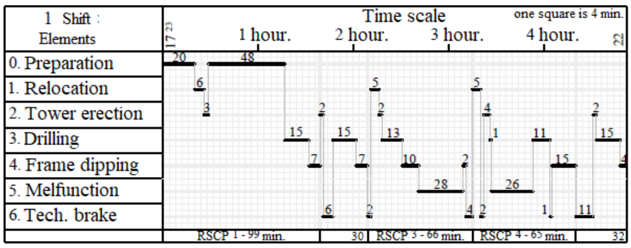

Fig. 8: Photo-fixation sheet of the first shift showing the duration of each element in minutes

During the first shift, there were breakdowns, which caused a considerable loss of time. The reason is the use of outdated basic equipment, which, on the other hand, is affordable and quick in payback in modern economic conditions. During the 2nd shift 3 RSCP and 16 soil-cement elements (SCE) were made (fig. 9).

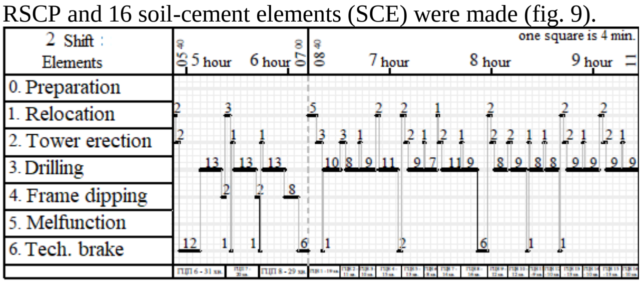

Fig. 9: Photo-fixation sheet of the second shift showing the duration of each element in minutes

From the last sheet, it's getting clear that manufacturing the SCE requires much less time than RSCP. During the third shift, a crew manufactured 6 RSCP and 8 SCE (fig. 10).

The listed above sheets give the complete perception of DSM technology for foundations work at oil and gas storage facilities construction.

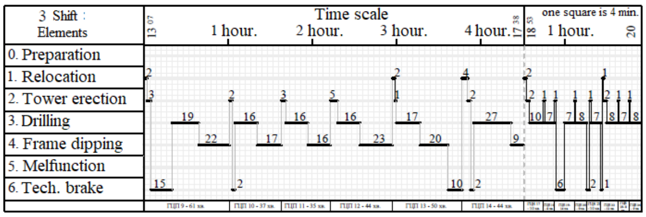

Fig. 10: Photo-fixation sheet of the third shift showing the duration of each element in minutes

It should be noted that "drilling" element is "supplied" by the operation of a grout mixing station which operates the exact same amount of time. Using the method of Prussak [9] we can calculate the normative time required for manufacturing the RSCP and SCE (tab. 1).

Table 1: The obtained field data processing

Elements and respective units	Total amount of time for an element, min.	Total amount of labor for an element	Specific time, min./el.unit	Transition index	Time spent for an element
Preparation works, 1 cycle	68	1	68,00	0,05	3,4
Relocation of a rig, 1 relocation	29	8	3,63	0,36	1,3
Drilling tower installation, 1 cycle	33	14	2,36	0,64	1,5
Drilling, 1 drilling to 8 m depths (repeat 3 times)	220	112	1,96	5,10	10,0
Frame instalation, 1 fram	164	14	11,71	0,64	7,5
Melfunction, 1 repair cycle	54	2	27,00	0,09	2,4
Tech/ brake, 1 brake	75	11	6,82	0,50	3,4
Grout supply, 0,5 m^3 for 1 pile	39	14	2,79	0,64	1,8
Total	682				31,3

The normative time for RSCP manufacturing is 31.3 min./m^3. By the same manner, the normative time for SCE manufacturing is 10.35 min./m3 which confirms our observations. The suggested method can be applied to any work or process in the oil and gas industry. The accumulation of normative time data for similar processes in different conditions and enterprises enables making a justified decision on whether or not the industry organized well.

The manufacturing of SCE requires 3 times less time, nevertheless, it's carrying capacity and depth are different. For that reason, these parameters require additional research.

Using the data presented, we can show correlation between the depth of RSCP or SCE and the duration of its manufacturing. This correlation is better approximated by the second degree polynomic function (fig. 11).

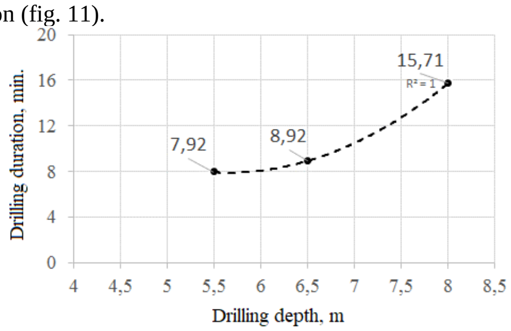

Fig. 11: Drilling duration – depth correlation

The presented above correlation shows that it's possible to compare drilling processes characterized by periodical lifting the drilling equipment to the surface in a scientifically justified manner only if the drilling depth is constant.

It wouldn't be correct to relate the time of drilling to 1 linear meter in order to "extrapolate" cost rates developed for one specific depth into another one.

3. Conclusions

The normative time needed for manufacturing the 1 m3 of reinforced soil-cement piles and soil-cement elements has been calculated using the engineer's Prussak method. The photo-fixation sheets of deep soil mixing technology of foundation work at oil and gas storage facilities are shown.

The presented calculation method can be implemented into the oil and gas industry as a tool for assessing the level of technological organization at a particular enterprise and the whole industry. That will be possible under a condition of accumulation a large enough database on industrial and manufacturing processes in various construction sites and conditions.

Technical capabilities of a contractor are crucial, since using the out-dated equipment causes malfunctions which take a lot of time to be fixed back to normal. On the other hand, utilizing a modern powerful equipment can decrease machinery time but the cost price of a product will be increased.

In the current state of the Ukrainian economy when there is no steady flow of construction contracts, the use of a modernized and repurposed outdated equipment is a temporary way for averagely sized contracts to stay in business.

It has been established that a correlation between the drilling depth and time is nonlinear. That means that new cost-rates for different depths of drilling cannot be obtained by the simple "extrapolation" of existing ones.

The comparison of SCE and RSCP manufacturing procedures shows that SCE are being made faster and the process is dynamical, but RSCP, in turn, provides higher carrying capacity.

The materials provided by this paper allows to plan a construction schedule for foundation works at oil and gas storage facilities more efficiently, eliminate the time gaps between the construction of different elements since it's possible now to predict the duration of well-drilling processes.

The pile foundations are considered to be the most convenient type of base for oil and gas storage and transportation facilities. RSCP and SCE manufacture by DSM technology proved to be the most economical compared to other variants. Given that oil and gas fields usually located in cross-country areas with poor infrastructure, the DSM technology would be most useful as it doesn't require transportation of concrete and grave, and all manufacturing processes are carried out in situ.

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