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## Estimating the amount of labour and materials needed for manufacturing the reinforced soil-cement piles by deep soil mixing technology

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### 1. Introduction

Engineer faces the problem of correct cost choosing during calculation of the estimate for the project which involves manufacturing of the reinforced soil-cement piles (RSCP). Ukrainian national regulations do not contain direct cost for this kind of work. The reason is that the exact amount of labor, time and building materials necessary for manufacturing the 1 m<sup>3</sup> of RSCP are not investigated.

### 2. Literature overview

A lot of publications devoted to the deep soil mixing (DSM) technology of manufacturing the soil-cement piles [1-4]. In [5] author has published experimental research data on the manufacturing of the RSCP as well as a comparison of different kinds of foundation for the same building. Sources [5, 8] describe the complete technological sequence of DSM technology. Source [9] contains regulations on the procedure of approval and implementation of newly-developed costs.

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### **3. Test methods**

In order to investigate DSM technology we used time study method which is described in [6, 7]. It's a traditional method which allows discovering a necessary information for costs calculation. Until now this method remains the best tool of research the different new technologies.

### **4. Results and their presentation**

Listed above papers pay no attention to the amount of workers' labor and operational time of machines. There is no data that can be used to compile a precise cost for the process of manufacturing the RSCP by DSM technology.

It is necessary to investigate DSM technology with time study method. This investigation aimed at discovering spends of the labor and building materials for manufacturing the 1 m<sup>3</sup> of RSCP. It's necessary to calculate the normative value of time needed for this process as well.

Nowadays if there is no direct cost for some process, during estimate calculation, engineer adopts existent cost which is technologically close to the actual process. For example, for soil-cement piles, we can use the cost that initially calculated for concrete piles. Then we should correct material and machines to the ones that have been used in fact. However, it is forbidden to correct more than two cost parameters without authorities' approval. Hence, the costs that aren't corresponding precisely to the actual process are being applied. As the result, estimate data differs from the actual process of work on the construction site.

That is why calculation the precise cost for the process of manufacturing the RSCP is an actual matter for an accurate engineering management. Ukrainian Ministry of Regional Development allows costs to be developed by particular enterprises in order to provide normative basis for its activity in proper spheres. During development of cost for manufacturing the RSCP, it's obligatory to take into account a complete technological sequence of works, values of labor and material resources as well as guaranteed quality of works. Costs developed in this way are called "Standards of organizations of Ukraine" and they shouldn't contradict the National Standards.

The process of manufacturing the foundations for a civil building is under investigation here. Construction site locates on Kagamlyka st. in Poltava, Ukraine. Considering geological conditions, engineer decided to use piles for reaching firm strata. Its length should've been

8,15 m. In this area, there were a number of existing buildings located close to each other. Therefore, we couldn't use driven piles. On the other hand, soil-cement piles capable of being manufactured on site by DSM technology do not affect nearby buildings in any way. The diameter of these piles was 0,45 m. We addressed the weak strength of soil-cement with the application of steel reinforcement. Reinforcing bars' length was 1 meter. Aside from that, we used some outdated equipment that we repurposed to use in DSM technology. Listed above peculiarities differed technology we used from other conventional methods. Therefore, discovering the precise spends of labor, time and building materials was advisable.

The papers [5, 8] described the essence of DSM technology. From technological point of view, it is a complex mechanised process. It performed by a group of workers: boring machine operator, mixing station operator, concreter's assistant. Mechanized work was performed with the boring machine on automobile chassis БМ-811М and the mixing station.

Manufacturing the RSCP by DSM technology consists of following procedures: supports deployment, boring tower deployment, boring (supplied with cement mortar providing its operation), reinforcing with steel bars, relocation the boring machine to next pile (fig. 4.1.)



*Figure 4.1. Deep soil mixing technology of manufacturing the reinforced soil-cement piles: a) supports deployment, b) boring tower deployment, c) boring, d) reinforcing with steel bars, e) relocation the boring machine to next pile, f) mixing station*

This technology contains a number of simple operations which require a small amount of time. Excessive division of the technology only complicates the process of its research. Among this simple operations are the supports removal, underlying the supports with wooden boards, soil removal from auger during boring, etc. Time spent for these elements was included in the main procedures listed earlier.

We used grouped kind of time study method for this research. One researcher observed the group of workers. We used a graphical way of data collection (fig. 4.2.) This method allows compiling a general view of the whole process. It also simplifies the process of analyzing the technology of manufacturing the RSCP.

Numbers on this diagram depict the time spent for the performance of each particular procedure. The accuracy of measurements was 1 minute.

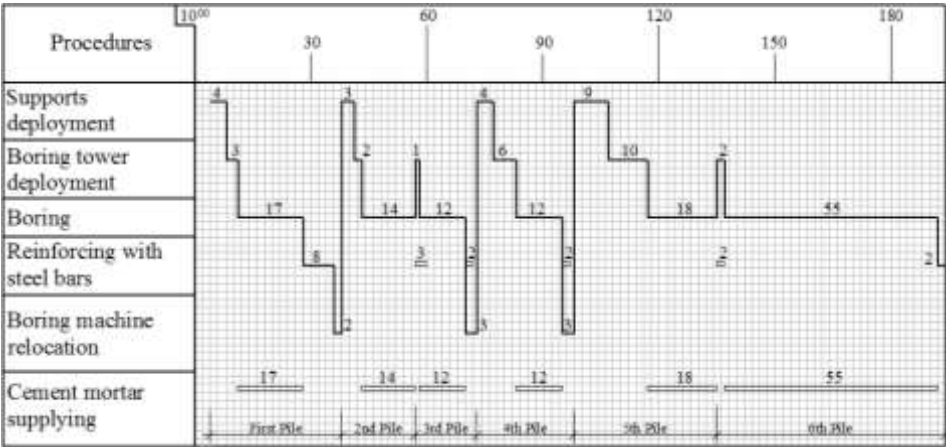


Figure 4.2. Diagram of time study

Workers have manufactured 6 RSCP within 3 hours from morning till the noon. The total volume of these piles is 7.77 m<sup>3</sup>. We spent 1450 kg of Portland cement and 3 m<sup>3</sup> of water for this. For the third and sixth piles, the procedure of supports deployment is absent (see pic. 2). The reason for that is the ability of boring machine to rotate and extent without relocation of the chassis. It enabled us to manufacture some piles staying at the same position, thus, saved working time. In this case, we've manufactured 2<sup>nd</sup> and 3<sup>rd</sup> RSCP from the same position as well as 5<sup>th</sup> and 6<sup>th</sup>. For this reason, the procedure of relocation is absent for the 3<sup>rd</sup> and 5<sup>th</sup> RSCPs. We've spent more time for manufacturing the 6<sup>th</sup> RSCP because of a few

malfunctions of the boring machine. Despite the significant time of preparation works we still had malfunctions due to outdated equipment, but on the other hand, it didn't take long to find spare details. Another source of the malfunctions is the equipment working under a high pressure. Occasionally, workers have to do a repair job, because malfunctions in this equipment manifest themselves only when the boring tool is already operated underground.

The table below shows the research results processing. Result processing is carried out using the method of average arithmetic with applying a method of finding the improved average [7]. The essence of this method is finding arithmetic average from values of timing sequence excluding those values which differ sharply as a result of random circumstances. This traditional methodic is an effective way of processing time study results. This methodic provides a necessary material for designing the cost. We can calculate the amount of labor required for manufacturing the 1 m<sup>3</sup> of RSCP.

Table 4.1. Research results processing

Procedure, measurement units	Time sum	% of total time	Time for 1 cycle (RSCP)						Improved average
			1	2	3	4	5	6	
Supports deployment, mach.-min.	20	6,1	4	3	0	4	9	0	2.2
Boring tower deployment, mach.-min.	24	7,3	3	2	1	6	10	2	2.8
Boring, mach.-min.	128	39,1	17	14	12	12	18	55	14.6
Cement mortar supplying, mach.-min.	128	39,1	17	14	12	12	18	55	14.6
Reinforcing with steel bars, hum.-min.	19	5,8	8	3	2	2	2	2	2.2
Relocation, mach.-min.	8	2,6	2	0	3	3	0	0	1.3
Total	327	100	51	36	30	39	57	114	

We have work of 3 kinds:

- manual work of concreter's assistant;
- mechanized work of boring machine operated by its operator;
- mechanized work of mixing station, operated by concreter.

We can separate amount of labor spent by workers and machines for work of each kind.

Table 4.2. shows this spent measured in machine-minutes and human- minutes.

Table 4.2. Labor spent for work of each kind

Kind of work, measurement unit	Time	Time spent for manufacturing 1 RSCP
Work of concreter, hum.-min.	19	2.45
Work of boring machine, mach.-min.	180	23.17
Work of mixing station, mach.-min.	128	16.47

Thus, we can calculate following normative values of labor spent:

- labor spent by workers: 2.45 human-minutes;
- labor spent by machine operators: 39.64 human-minutes;
- labor spent by machines: 39.64 machine-minutes.

These are the values we aimed to obtain. Using this data in conjunction with wage rate book, we can calculate direct cost of the work. Based on the values of labor spent, a precise cost for the process might be calculated. Under different conditions, the cost would be different either. For example, a high cost may indicate that we use very expensive equipment, or it's just bad management. It is necessary to find criteria allowing us to compare different ways of work organization and find the best of them.

Normative value of time spent for manufacturing the 1 m<sup>3</sup> of RSCP is the quantitative indicator, which describes the efficiency of DSM technology in particular conditions. Algorithm of its calculation is shown in [7]. It requires data from table 1 only. First of all, we need to find the sum of time spent for each procedure (see table 4.3., column 2). Then, we calculate the amount of work in measurement units of the particular procedure (m<sup>3</sup>, units, etc.). Dividing the amount of time by manufactured product, we'll find partial time spend. Knowing the amount of manufactured product, we can find the coefficient of conversion. It's a number of each procedure's measurement units in a single unit of manufactured product. We'll find time spent for each procedure by multiplying partial time spends and the coefficient of conversion. The sum of time spent for all procedures is the normative value of time spent for manufacturing the 1 m<sup>3</sup> of RSCP.

Table 4.3. Calculation the normative value of time spent

Procedure, measurement units	Time, spent on element, min.	Partial time spends, min./measurement unit of element	coefficient of conversion	Time spent, min./m <sup>3</sup>
1	2	3	4	5
Supports deployment, 1 unit	20	5	0.51	2.55
Boring tower deployment, 1 unit	24	4	0.77	3.08
Boring, 1 unit	128	21.3	0.77	16.4
Cement mixture supplying, 0.5 m <sup>3</sup>	128	21.3	0.77	16.4
Reinforcing with steel bars, 4 bars	19	3.2	0.77	2.46
Relocation, 1 unit	8	2.7	3.9	10.53

Normative value of time spent for manufacturing the 1 m<sup>3</sup> of RSCP is 51.43 minutes. This value depends on the technology of work, qualification of workers, management and all significant factors of manufacturing process. It is necessary to collect time study data from different construction sites and compare it, using described criteria. Those with the least normative value of time spent can be used for calculation the precise cost for DSM technology.

## 5. Discussion

A similar investigation should be carried out at least at 3 construction sites before implementing the cost into practice. During that, new factors which affect the process might be discovered. Those factors might lead to further complication of the cost. Aside from that, each investigation should last at least 6 shifts. That will provide reliability of the results.

## 6. Conclusions

We've investigated DSM technology with time study method for the first time. Using reliable methodic, we discovered spends of the labor and building materials for manufacturing the 1 m<sup>3</sup> of RSCP. We've calculated the normative value of time needed for this process. This investigation results will simplify engineering management process where DSM technology applied.

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**Abstract**

This paper deals with the process of pile foundation installation for a civil building. Deep soil mixing technology is under investigation. We've used time study method to obtain a necessary material for designing of cost. We've calculated normative values of time, workers' labor and building materials for the manufacturing of a 1 m<sup>3</sup> of reinforced soil-cement pile for the first time. Presented results allow adequate calculation of an estimate and designing of a project for construction with an application of the reinforced soil-cement piles.

**Keywords:** estimate, cost, soil-cement, piles, technology.