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NORMATIVE OBSERVATIONS OF DEEP SOIL MIXING TECHNOLOGY OF SOIL-CEMENT PILES MANUFACTURING

This article deals with the complex process of pile foundation erection for civil building. Deep soil mixing (DSM) technology is used. In order to find material, necessary for the proper costing designing normative observations of DSM technology of RSCP manufacturing were carried out using method of photo recording. Using that, labor spends of machines and workers for a single unit of production as well as norm of time were calculated. Comparison algorithm that can be used for different techniques, conditions ways of construction organization and other factors is presented. This methodic allows determining of the influence of different factors of construction production and environment to the process of RSCP manufacturing. Compiled results of this investigation and follows ones will allow adequate costing system for DSM technology to be created given that a necessary amount of a practical data will be accumulated.

Keywords: *pile, soil-cement, reinforcement, technology, costing, labor costs, timing, norm.*

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НОРМАТИВНІ ДОСЛІДЖЕННЯ БУРОЗМІШУВАЛЬНОЇ ТЕХНОЛОГІЇ ВИГОТОВЛЕННЯ ҐРУНТОЦЕМЕНТНИХ ПАЛЬ

Досліджено комплексний процес улаштування пальових фундаментів для громадської будівлі. За допомогою методу фотообліку здійснено нормативні дослідження бурозмішувальної технології виготовлення ґрунтоцементних армованих паль. У результаті проведених досліджень було отримано матеріал, необхідний для аналізу величини затрат робочого часу та розроблення норм і розцінок. Уперше визначено норму витрат часу на кубічний метр армованої ґрунтоцементної палі, норми витрат праці машин і робітників. Наведено методику, яка дозволяє здійснити порівняльний аналіз різних технологій виконання робіт. Вона також дозволяє визначити величину впливу різних факторів будівельного виробництва та навколишнього середовища на процес виготовлення паль. За умови накопичення достатньої кількості практичних даних скомпільовані результати проведеного дослідження та наступних за ним дадуть можливість створити адекватну систему розцінок для бурозмішувальної технології виготовлення паль.

Ключові слова: *паля, ґрунтоцемент, армування, технологія, розцінка, трудовитрати, хронометраж, норма.*

Introduction. The problem of correct costing choice emerges before engineer, during developing of design-costing documentation (DCD) for manufacturing of reinforced soil-cement piles (RSCP). Costing norms don't contain a straight costing corresponding to this complex process of performance of works.

Review of latest research sources and publications, where problem solution initiated. Lots of publications of Ukrainian and foreign scientists devoted to DSM technology of soil-cement piles manufacturing [1 – 4]. Article [5] represents data concerning experimental manufacturing of RSCP and economic comparison with other possible foundation solutions. Sources [5 – 8] describe complete technological sequence of DSM technology. They contain all details of the process that is under investigation here. Source [9] contains regulations on the procedure of approval and implementation of newly-developed costing norms.

Identification of general problem parts unsolved before. In most of publications labor costs of workers, operation of machines and mechanisms for manufacturing of 1 meter of RSCP remain out of attention. The influence of works performance technology on the amount of labor costs is not investigated enough.

For now, during DCD performance, if a straight costing is absent, than, as a rule, one of already existing ones should be used. Costing with the most similar technology to described process should be used. For example, manufacturing process of ferroconcrete piles is being taken instead of RSCP. Although material of pile and building machines might be changed to practically used ones inside the content of costing. But it's forbidden to change more than two costing parameters without approval of Derzhbud of Ukraine. Thus norms of time and work are used but it isn't justified with normative observation. As a result these norms might differ from actual values.

That's why development of a proper costing for the process of manufacturing of RSCP is actual task for correct organization and planning of construction production. Nowadays according to the letter Minregion of Ukraine from 17.01.2015 # 7/15-425 "Concerning costing norming in construction", enterprises in respective spheres of activity and considering its economic and professional needs are granted with the right to organize works on standardization and in particular to develop, revise and revoke standards. Standards of organization of Ukraine (SOU) are approved with its own order for an enterprise. During developing of SOU technology of works performance with ensuring necessary quality should be considered with composition of works, indicators of labor and material-technical resources. Aside from that SOU shouldn't conflict with the national standards [9].

Formulation of the problem. Detection of RSCP manufacturing components necessary for designing and compiling of a costing, calculation of labor costs and norm of time for this process are the objectives of this research.

Basic material and results. It is known [6, 7] that using the method of photo recording allows to research all kinds of working time spends. This method allows to detect data necessary for norms compilation. It is the most widespread type of normative observations.

The process of foundation installation for civil building is under investigation. Construction site is located in dense building on Kagamlyka st. of the city of Poltava.

RSCP are used as a foundation. It was reinforced with steel bars. Piles diameter was 450 mm, length – 8.15 m. Piles were reinforced to the depth of 1 m. Length of piles was determined of the condition of reaching strong enough layer of soil. Manufacturing of some piles was provided in close proximity to existing buildings. DSM technology was used. Water and electricity supply of construction machinery was carried out through the connection to existing engineer networks.

The essence of DSM technology is described in [5, 8]. From technological point of view DSM is a complex mechanized process (further process). It was performed by brigade

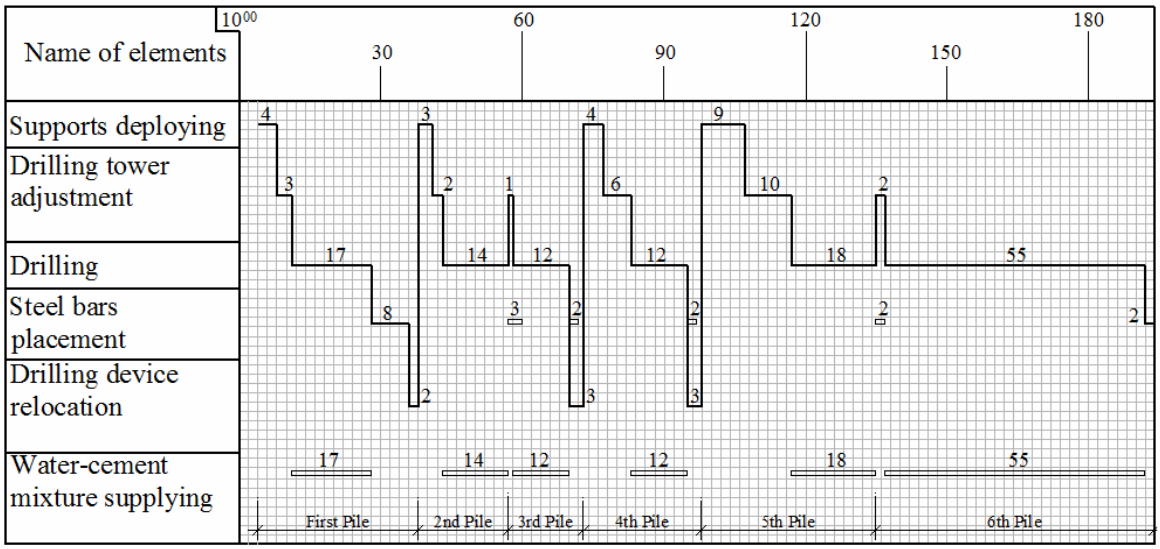
consisting of driver of drilling device, concreter at the mixing station and concreter assistant. Mechanized work is performed with drilling device БМ-811м on automobile chassis and the mixing station.

The process consist of following elements: supports deploying, adjustment of drilling tower, drilling, reinforcing bars placement into soil-cement, relocation of drilling device to next pile and supply with water-cement mixture which ensures operation of drilling device (pic. 1).

Picture 1 – Components of the process:
a – supports deploying; b – adjustment of drilling tower;
c – drilling; d – reinforcing bars placement into soil-cement;
e – relocation of drilling device to next pile;
f – supply with water-cement mixture

There are a lot more elements in the process. But overdoing this will lead to complication of technology analysis process because small elements take only a small part of total time. For example, operations of supports removal prior to relocation of drilling device, stacking of wooden shields under supports, removal of soil during drilling, instruction of driver concerning correct position of drilling tower are not shown.

Group type of photo recording was used, wherein one observer keeps records of whole brigade. Graphic way of time keeping was used (pic. 2); this allows compiling a general concept of the whole process. It is easier to analyze technology of piles manufacturing using this form. In the graphic shown below numbers represent time spent on performance of particular element. Accuracy of measurements is 1 minute. As graphic on pic. 2 shows, 6 RSCP were manufactured from the beginning of work day till the dinner break. This amounts 7,77 m^3 in the measurer of production. 1450 kg of Portland cement and 3 m^3 of water were used for piles manufacturing.



Picture 2 – Fragment of blank of photo recording graphic

As we can see on pic. 2 the element of supports deployment is missing for third and sixth RSCP. The reason for that is a capability of drilling device of rotating and longitudinal displacement without changing position of automobile chassis. This allows to perform drilling a few RSCP from a single station. In our case drilling of the 2nd and 3rd as well as 4th and 6th RSCP were performed from a single position. That is why the element of relocation is absent in 2nd and 5th RSCP. Manufacturing of 6th RSCP took more time than others because of a few breakings of the drilling device during operation. That resulted in such kind of a delay.

However breakings take place despite long enough time (2 hours) spent on preparing works. The reason is a use of equipment working under a pressure. Slight breakings are not likely to be discovered until manufacturing of RSCP is initiated when supplying with water-cement mixture starts. Since the process is cyclic result data processing might be represented as shown in table 1.

Result processing is carried out using method of average arithmetic with applying a way of finding the «improved average».

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.

Using data from table 1 it's possible to define labor costs for a single unit of production (1 m^3 of RSCP). In this case 3 types of work are presented:

– handy work of concreter assistant;

– mechanized work of drilling device, operated by driver;

– mechanized work of mixing station, operated by concreter.

Let's separate labor costs of workers and machines for each type of work measured in hum.-min. and mach.-min. (table 2).

Table 1 – Processing of results of normative observations

Name of element, measurement units	Sum of time costs	% 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
Adjustment of drilling tower, mach.-min.	24	7,3	3	2	1	6	10	2	2,8
Drilling, mach.-min.	128	39,1	17	14	12	12	18	55	14,6
Water-cement mixture supplying, mach.-min.	128	39,1	17	14	12	12	18	55	14,6
Steel bars placement, 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	

Table 2 – Labor costs for all types of work

Type of work, measurement unit	Total time costs	Time costs for a single unit of production
Work of concreter, hum.-min.	19	2,45
Work of drilling device, mach.-min.	180	23,17
Work of mixing station, mach.-min.	128	16,47

So in this way, we can obtain follow norms of labor costs for 1 m^3 of RSCP:

– labor costs of workers which are not engaged in machine handling: 2,45 hum.-min.;

– labor costs of workers which are engaged in machine handling: 39,64 hum.-min.;

– costs of machine time: 39,64 mach.-min.

An important indicator of technologic level of the process of RSCP foundation manufacturing is time norm for manufacturing of 1 m^3 of production for particular conditions of production organization. Knowing this indicator will give an opportunity to compare among each other the work of these machines and workers at different construction sites under different ways of organization of construction production. Also this will enable one to compare different technologies of manufacturing the same kind of piles and to define the best of it.

In the source [7] the algorithm of norms of time calculation is shown. It requires data from table 1. So, amount of minutes spent on each element of the process should be defined first of all (second column of table 1). Amount of work for each element in a measurer of element should be defined. Partial time cost for each element and transfer coefficient to measurement units of completed production should be defined next. Time costs of each element are defined by the way of multiplying of two values described above for each element respectfully. The sum of norms of time for each element should be defined and that leads to clear norm of time obtaining for a single unit of production (table 3).

Thereby sum of values in 5^{th} column is 51,43 min./m^3. This value is the norm of time spent for a single unit of production with described technology of piles production and the way of production organization.

Using the normative data obtained above and tariff qualification handbook one can calculate the cost of machine exploitation, workers salary, the cost of production manufactured according described technology.

Table 3 – Calculation of clear norm of time for a single unit of production

Name of element, measurement units	Time, spent on element, min.	Partial time costs, min./meas. unit of element	Transition coefficient	Time costs, min./m^3
Supports deployment, 1 unit	20	5	0,51	2,55
Adjustment of tower, 1 unit	24	4	0,77	3,08
Drilling, 1 unit	128	21,3	0,77	16,4
Mixture supplying, 0,5 m^3	128	21,3	0,77	16,4
Steel bars placement, 4 bars	19	3,2	0,77	2,46
Relocation, 1 unit	8	2,7	3,9	10,53

Conclusions. Normative timing investigations of DSM technology of RSCP manufacturing were carried out for the first time. Obtained results of timing might be used during costing compilation for RSCP manufacturing under condition of accumulation enough practical data from different construction sites. Norms of time costs and labor of workers and machines during RSCP manufacturing were defined for the first time. Offered comparing method might be used for different ways of production organization and technologies of RSCP manufacturing comparison. It enables one to define the most efficient way of works performance and organization of production.

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