Improving design solutions for the organization of construction production and the construction site equipment taking into account environmental safety during the reconstruction of facilities

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Abstract. The designing process of the work organization for the buildings’ reconstruction has a number of features, such as the cramped conditions, tight deadlines, increased danger of work, etc. The design solutions’ development for the reconstruction work organization in any case should not lower the safety level for the construction workers and personnel of the reconstruction object, as well as damage the environment, in particular, air pollution by the dust particles from the construction processes, therefore, work execution projects should take into account the organizational and technological measures for labor protection and environmental safety of the territory where the reconstruction works are carried out. Environmental management included in the reconstruction of facilities should cover all the time both the space of the construction site and the processes organization that can minimize harm to the neighboring territory. This article discusses the measures to implement environmental monitoring in the work schedule at the construction site and construction equipment with cost-effective measures to combat the air pollution. The introduction of economically viable means of combating air pollution into design solutions, as well as the construction production effective organization, reducing the environmental burden on the territory, will allow the contractor to increase its competitive advantage when participating in tenders and determining the contractual price for the building reconstruction. The choice of cost-effective protective measures can save the costs, subsequently determining the profit of reconstruction work.

Introduction

Designing in a short time period when approaching the reconstruction works replaces the construction organization project’s development as part of the working documentation with the development of local work projects for the individual construction processes, most often where the large volumes of work are planned. The design solutions’ development for the reconstruction work organization in any case should not lower the safety level of the construction workers and personnel of the reconstruction object, as well as damage the environment, in particular air pollution by the dust particles from the construction processes. In construction work projects, it is necessary to develop the measures to
protect human labor and protect the atmosphere and builders from dust and construction debris, noise, as well as the increased fire safety measures should be introduced.

The design solutions for the reconstruction work organization have a number of features:

1. often, reconstruction work occurs without stopping the functional process of the building; accordingly, developed project of work production should be agreed with the administration of the facility in operation;
2. when performing work in cramped conditions, it is necessary to develop the specialized methods for the production of specific construction works, and implement their technological maps, linked to the functional processes at the facility;
3. short deadlines for the reconstruction;
4. conditions of increased danger of work;
5. operational adjustment of the work schedule in the work process;
6. environmental monitoring during the reconstruction process by the contractor under the relevant environmental authorities’ supervision. Environmental monitoring is divided into two levels: regular monitoring by the contractors and spot checks by the customer [1].

Environmental monitoring should meet the following requirements:
- the monitoring content should comply with the requirements of the Environmental Impact Assessment (EIA) and the Department of Environmental Protection;
- specific monitoring points, frequency and monitoring points are determined by the customer and contractor.
- monitoring is carried out by the general contractor or a third-party supervisory body specified by the customer. All monitoring results should be summarized and submitted to the Committee for Environmental Protection for analysis.

Environmental management included in the reconstruction of facilities should cover all the time both the space of the construction site and the organization of processes that can minimize harm to the neighboring territory.

Materials and methods

The reconstruction project should include:

1. The schedule for the building reconstruction. Here, the terms, sequence and coordination of technological processes are established with the maximum possible combination with the functional processes of the facility and additional backup works (tasks) to optimize processes, to reduce the environmental load on the territory is indicated.

Within a month after signing the contract, the general contractor must prepare and submit the environmental management plan of the contractor for consideration and approval to the customer. In the plan, the contractor should clearly indicate the measures that should be taken by the contractor to reduce the possible environmental impact. The plan should contain at least the following content:
- a summary of the contractor’s statutory and contractual obligations for environmental protection, as well as the measures that should be taken by the contractor to supervise, monitor and audit its environmental management at the construction site to ensure compliance with these obligations;
- an organizational chart of the environmental management and its implementation in the schedule of construction processes at the place of work of contractor workers;
- a detailed list of environmental impact forecasts, which should include: possible environmental impacts associated with the reconstruction project (in particular, air, dust, noise, water and waste pollution), possible impacts, proposals and implementation plan to eliminate or mitigate the impact; environmental emergencies that may occur at the facility (for example, the release of a dust cloud or chemicals during dismantling), as well as emergency response procedures;
- procedures for assessing the environmental management effectiveness.

These conditions are ensured by the measures developed or implemented by the contractor – on the basis of documentation on previously completed similar facilities and works. The preparatory period
work for the facility reconstruction, taking into account environmental safety, is differed in their composition:

- the device of temporary barriers, coatings, partitions with the use of the protective structures that prevent the spread of dust pollution, is shown in Figure 1 [2]. The technical result of this installation is to maximize the dust absorption, including fine dust. The largest number of shields is installed in the places of local dust pollution of atmospheric air to protect both the personnel at the construction site and the population living or located near the territory of the reconstruction;

- protection of existing communications or their transfer;

- device of openings for mounting mechanisms;

- development of a temporary water supply system for the dust control implementation at a construction site;

- the measures to protect the improvement elements or equipping the site with the aim of reducing soil erosion during reconstruction work.

Figure 1. Diagram of the dust shield mounted on the barrier and scaffolding on the site: 1 - a wooden frame of softwood, 2 - gunny (strong, dense durable material), 3 - glazing beads for fastening, 4 - clamps for fastening to the barrier, 5 - bolted connections, 6 - nuts for connection, 7 - mounting bracket for fastening to scaffolding and fencing.

All elements of the reconstruction schedule are agreed with the customer. Particular attention is paid to the work schedule, since in some versions for the construction work objects’ reconstruction can be carried out in one room by the functional processes, where, in turn, the health of both construction workers and staff in the building should be given increased attention.

The reconstruction schedule composition for the objects of medium complexity is shown in Figure 2. The average number of reconstruction works and events varies within 300: 200 - construction processes at the site, 30 - preparation for reconstruction (design, preparation of the territory), about 70 - administrative support for the reconstruction and environmental monitoring. In the course of planning the work organization at the facility reconstruction site, the control simplification methods based on the Pareto law [3] and the Juran rule [4] should be used. This method suggests that 80% of the results of any project is determined only by 20% of its constituent elements. During the design, the work and processes with the highest risk level are determined, where the developed monitoring program is organized with the detailed indicators’ calculation. The control of other processes is carried out in the aggregate by the total indicators. A large number of limiting factors require interactivity elements from the reconstruction schedule [5].
in addition to the main composition of the measures, the following elements:
- the boundaries of the site or zone of the reconstruction work, the types of its fencing and the labor protection measures;
- existing and temporary networks and communications;
- permanent and temporary roads, traffic patterns of vehicles and mechanisms;
- installation sites for construction and lifting machines as well as the elevators for materials, their paths and operation zones;
- placement of permanent, constructed, reconstructed and temporary buildings and the structures for the workers’ sanitary services;
- locations of the geodetic center marks;
- hazardous areas, passageways into the building and structures for personnel and workers;
- power supply and construction site lighting;
- places for the construction waste collection and disposal;
- sites and premises for the storage of materials, sites for large-scale assembly of structures, areas for performing work of increased danger [6].

In order to combat air pollution and prevent its spread into the environment, the organization of construction production and the construction site equipment, both reconstruction and construction as a whole, is to include the facilities and protective equipment that prevent or limit the release and spread of negative impacts. These measures are important for many factors: protecting the environment of the territory where work is launched, reducing the harmful effects on the construction workers’ health and the health condition of the people living near the reconstruction site. There are various types of equipment and facilities that ensure environmental protection, the main ones are presented in Table 1.

Table 1. The main sources of air pollution and methods of dealing with them.

| The main sources of air pollution | Ways to combat pollution               |
|---------------------------------|---------------------------------------|
| Dust                            | Use of dust removal devices due to gravity and inertia |
|                                 | Use of cyclone dust collectors         |
|                                 | Use of filters                         |
|                                 | Use of bag dust collectors             |
|                                 | Use of electrostatic dust collectors   |
| Gaseous pollutant               | Use of various adsorption filters for air purification |
|                                 | Use of various treatment equipment     |

Often the introduction of these facilities is a temporary but rather expensive process, their use slows down the technological processes’ execution, which affects the construction production cost, respectively, the cost of construction and installation work and the profit of the contractor. In this regard, the contractor should choose the most cost-effective solutions that do not require major
investments. In such conditions, the question of using compact, inexpensive equipment and installations at the workplace, in cramped conditions, the development of organizational and technological measures in the project for the production of work, avoiding the cost of reconstruction of buildings and structures both standard and in cramped conditions arises [7].

3. The delivery schedules of the building structures, products, materials and equipment at the facility with the data developed on the basis of the resources supply for each site with the application of picking checklists should be synchronized. The schedule development of incoming materials to the construction site should take into account the work schedule and the number of people on the site to reduce health damage, for example, when transporting the bulk materials.

4. Technological maps are developed for the execution of certain work types with the inclusion of operational quality control schemes, a description of work production methods, an indication of labor costs, need for materials, machines, equipment, protective equipment for workers, as well as the sequence of dismantling work during the buildings’ and structures’ reconstruction [8 ]. The organization of the health protection for the construction workers from the effects of dust pollution should oblige the contractor to develop the measures to equip the workplace with compact, budget-friendly protective equipment, which is possible with the use of compact installations providing dust settling - fogging guns, shown in Figure 3.

Figure 3. Equipment diagram: 1 - housing, 2 - bedplate, 3 - internal water supply pipes, 4 - fan, 5 - nozzles, 6 - electromagnetic field source, 7 - air pump, 8 - filter, 9 - connection point with the water supply system.

5. There should be an explanatory note containing:
   - decisions substantiation on the works’ production, including those performed in the winter time;
   - need for energy resources and solutions for their renewal;
   - a list of mobile buildings and structures and devices with the calculation of needs and justification of the conditions for their binding to the sites of the reconstruction site;
   - measures aimed at ensuring the preservation and elimination of theft of materials, products, structures at the construction site, in buildings and structures;
   - measures for the protection of existing buildings and structures adjacent to the site from damage, environmental measures.

Discussion and Results
The study of technological work on the reconstruction of buildings and structures that emit the greatest pollution into the atmospheric air in the territory where the work is carried out showed the results presented in Table 2.
Table 2. Repair and construction work emitting dust pollution

| Name of repair and construction work | PM10, mcg / m3 | PM2.5, mcg / m3 | Dusting rate |
|--------------------------------------|----------------|----------------|--------------|
|                                      |                |                | Strong       | Moderately   | Weak         |
| 1 Plastering                         | 25             | 5              | *            |              |              |
| 2 Insulating                         | 5              | 1              | *            |              |              |
| 3 Preparatory                        | 30             | 10             | *            |              |              |
| 4 Installation of scaffolding        | 8              | 2              | *            |              |              |
| 5 Stonework                          | 17             | 3.4            | *            |              |              |
| 6 Installation of flooring           | 21             | 6.3            | *            |              |              |
| 7 Garbage collection                 | 28             | 11.4           | *            |              |              |
| 8 Painting                           | 21             | 8.9            | *            |              |              |
| 9 Finishing                          | 23             | 9.2            | *            |              |              |
| 10 Waterproofing                     | 16             | 6              | *            |              |              |
| 11 Thermal insulation                | 19             | 6.5            | *            |              |              |
| 12 Roofing                           | 11             | 3.3            | *            |              |              |

The process of introducing technological measures into the dusting process organization showed the following results, technical and economic indicators.

Comparison of standard solutions for the area dust suppression complex [9] and dust suppression units [10] showed the results of the need for significant financial investments in epy environmental protection reconstruction measures, which is not beneficial for contractors. The disadvantages of these solutions are, in addition to the significant cost of both equipment purchase and lease for the period of reconstruction, the high consumption of water spent on irrigation, the complexity of the nozzle design technical implementation for producing a highly ionized water-air mixture at the outlet, which does not significantly increase the dust suppression efficiency.

The most cost-effective is the use of a new technical solution, presented in Figure 3, a dust suppression gun, which includes a housing, a frame, water pipes, a fan, a filter, an air pump and a nozzle system, additionally includes the sources of constant electromagnetic field. The technical result is the creation of an electromagnetic field in the air, sufficient for the attraction of fine particles of dielectrics, dust particles of the smallest fractions. The small size and mobility of this installation, installation simplicity, construction net cost, determine the preference for this equipment application.

Summary
The implementation of the proposed measures increases the one-time labor costs for the additional work and, accordingly, the one-time salary and cost for their implementation. But these indicators will be significantly lower than the same criteria when using the organizational measures to improve environmental safety. For example, the use of walls, barriers, existing dust collection systems, including hydration, primarily, only due to the effectiveness of their work.

The introduction of economically viable means of combating air pollution into design solutions, as well as the effective organization of construction production, reducing the environmental burden on the territory, will allow the contractor to increase its competitive advantage when participating in tenders and determining the contractual price for building reconstruction. The choice of cost-effective protective measures will allow saving costs, subsequently determining the profit of reconstruction work.

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