

Organizational-and-technological solutions for installation of prefabricated roof coverings from roll materials

*Boris Zhadanovsky**, *Sergey Sinenko* and *Aida Mirzakhanova*

Moscow State University of Civil Engineering, 129377, Moscow, Russia

Abstract. Implementing the modern technological methods is recommended in the article, as well as performing some operations. It should be considered that small and medium-sized enterprises involved in the construction of industrial and civil facilities are also installing the roof coverings. The algorithm of technological operations is as follows: preparatory work; gluing a two-layer waterproofing roofing on freshly formed reinforced concrete panels; double rolling of the uncooled roll roofing after removing the panel from the steam chamber. The process of installing the waterproofing roofing has to be carried out in a specially equipped enterprise area. It is recommended to use the following domestic and foreign tools and equipment for above-mentioned operations. Such equipment is a truck crane (for example, KS-45717), a roof crane (KL-3), a temporary fence, a metal ruler, a tape measure, roller or a brush, a scraper, a roofing knife and a roller (weight is 100 kg). The rational methods of roofing installation (based on labor intensity) are presented. As was substantiated, the calculation of labor can change while improving the technology and the tools and equipment used. The quality control of operations is described, it involves visual inspections and the necessary measurements performed with a ruler. Optimal organizational and technological solutions, which allow to manage processes taking into account the safety of workers, were obtained. Fulfilling the labor safety requirements during construction (part 1 and part 11) is primary while installing the roll-up waterproofing roofing made of melting roofing material with the help of a solvent. In addition, it should be noted that the workplaces and storage locations with flammable materials and substances have to be provided with a portable fire stand, as well as with fire extinguishing and medical equipment. The conclusions and recommendations on organizational and technological solutions for installing the prefabricated roofing from roll materials by using mechanization means are presented. They are intended for developers of organizational and technological documentation, including flow charts, work projects, regulations, codes of rules. They will be useful for students, masters, graduate students studying for professions related to the production of building, erection and special works.

*Corresponding author: JadanovskiyBV@mgsu.ru

1 Introduction

One of the main promising areas for development of reinforced concrete roof structures for the mass construction of residential, public and industrial buildings is the construction of roofs made of prefabricated coating panels. Such panels simultaneously perform heat-bearing and waterproofing functions [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15].

The transition to installing the roofs from prefabricated panels will allow to reduce labor costs at the construction site, because about 30% of labor-intensive roofing work is transferred to the factory. This is especially important for the Far North and other regions, where climatic conditions are often unfavorable for roofing work carried out outdoors.

2 Materials and Methods

The prefabricated roofing panel is a load-bearing reinforced concrete panel (slab) with two waterproofing layers made of various types of fused roofing material glued during its manufacture. At the same time, the panel manufacturing technology remains unchanged [1, 2, 3, 4, 6, 7, 11, 12].

In order to prepare panels for waterproofing, a storage area for roofing felt rolls is equipped. Delivery of roofing feltrolls is carried out in containers in an upright position. It is advisable to store roofing feltrolls in an upright position, protected from direct sunlight under a canopy or in a closed warehouse. For preparatory work at the loading and unloading site, it is advisable to use a crane on a special chassis or a truck crane of the KS-45717 type. The tower crane is used only if it is available on the construction site and if it is possible to enter the service area of the site for loading and unloading operations.

The waterproofing for the panels is arranged from pre-cut sheets of roofing felt (roofing waterproofing material). Gluing the waterproofing layers against each other (the formation of pictures) and with the concrete of the panel is carried out by plasticization and by imparting adhesive properties with mastic roofing layers of roofing felt by moistening them with a solvent.

Prefabricated roofing panels are installed on the roof in the traditional way, taking care to prevent damage to the waterproofing of panels.

Waterproofing of joints between panels on the roof includes two layers of roof waterproofing material (roofing felt), the first of which is point-glued on one side. The second layer overlaps the first and is glued continuously. After waterproofing the joints, two layers of continuous waterproofing carpet are glued.

3 Results

The organizational and technological solutions recommended below are advisable in the construction and reconstruction of frame buildings for civil and industrial purposes.

Organizational and technological solutions were developed for installation of two waterproofing layers made of fused roofing felt. The two layers were glued to freshly formed reinforced concrete panels that have gained the necessary strength after heat treatment. The panels were manufactured at house-building plants and factories of reinforced concrete products using bench technology.

The list of considered works include the following:

- preparatory works;
- gluing the two layered waterproofing roofing to freshly formed reinforced concrete panels using the adhesive compositions;
- double rolling with a roller weighing 100-150 kg of an uncooled roll roofing after

removing the panel from the steam chamber.

Organization and technology of gluing waterproof roofing during panel manufacturing.

The process of installing a waterproof roofing should be carried out in a specially equipped area of the enterprise

Gluing of waterproof roofing must be carried out at an outdoor temperature of at least +5°C.

For the installation of a waterproof roofing, it is necessary to use a fused roofing material according to TU 21-27-35-78 of such grades as PM-500-2.0 and PM-42O-1.0 and other roofing roll waterproofing materials [4].

Lighting kerosene should be used as a thinner (plasticizer) of the mastic layer of roofing felt in accordance with GOST 4753-68 and others [4].

In order to use other solvents, it is necessary to preliminarily clarify the technological requirements for the dosage of the solvent and its effectiveness in each case.

The complete technological process of manufacturing the prefabricated panels includes the following operations:

- forming the supporting base of the panel;
- gluing two layers of waterproof roofing;
- heat treatment of the product;
- double rolling of the roofing.

Forming of panels (bearing base (layer) for a waterproof roofing) is carried out in accordance with organizational and technological solutions for manufacturing such panels. These solutions were developed by DSK or another scientific and research organization according to the certificate received.

In case there are any defects in the panel waterproofing layer, such as punctures, cuts and etc., the defects should be eliminated by gluing a patch of roofing material to the defective place.

Technological operations for gluing a waterproofing layer, as well as technical requirements and necessary mechanisms are presented in Table 1.

Table 1. Technical requirements, mechanisms and hand tools

Technological operations	List of works	Mechanisms and tools	Technical requirements	Brigade staff
Preparatory works	Construction camp development	Motor crane KS-45717	Maximum lifting capacity -25 tons	Assemblers 5g – 4 Strapper 4g – 1 Crane operator 5g – 1
	Arranging a place for receiving and installing roll materials on the roof	Roof crane KL-3	Carrying capacity up to 1 t	Crane operator 4g – 1 Strapper 5g – 1
	Arranging the fence for receiving location for roll materials	Temporary fence	Fence height no more than 1.1 m	Assembler 4 g – 1 Assembler 3 g – 1
	Placing the fire panels (portable) and a stand with a slinging scheme	—	The size of fire panel is 1400 x 1250 Complete set ShP -A class A Stand with a	Handymen 3g – 1

			slinging scheme is manufactured according to the requirements of Rostekhnadzor	
Preparing the roofing felt	Roll out the rolls of roofing felt on the site and keep them unrolled until the waviness disappears completely	—	In order to avoid cracking of the mastic layer, rolls of roofing felt should be kept for 24 hours at a temperature not lower than +12 °C before rolling	Thatcher 4 g– 1
Roofing felt cutting	Mark the rolled roofing felt into pieces with a metal ruler, tape measure and chalk in accordance with the cutting pattern for this panel; cut along the markup; mark pieces of roofing felt with chalk	Metal ruler, tape measure, roofing knife 1	Cutting straightness	Thatchers 4 g– 4
Laying the first layer of waterproofing	The cut sheet (piece) of roofing felt, which is first placed on the panel, should be moistened with a solvent (kerosene) at the rate of 0.080-0.1 kg/m ² from the side of the thickened mastic layer. Thatchers take the wetted sheet by the ends, turn it over and lay it on the freshly formed concrete surface of the panel with the wetted surface, and straighten it. Subsequent sheets are wetted and laid in a similar way.	Roller or brush, scraper 1	Roofing felts should be evenly moistened with solvent without gaps and drips	Thatchers 4 g – 2

	After laying the first layer of waterproofing, it should be rubbed with strokes to remove air bubbles.			
--	--	--	--	--

The first layer of waterproofing should cover the entire surface of the panel.

The second layer of waterproof roofing should recede from the panel edge (first layer) by 100 - 150 mm along the contour. The exceptions are cutouts in panels, where the upper layers of roofing felt are laid flush with the bottom layer only along the contour of the cutout (Fig. 1).

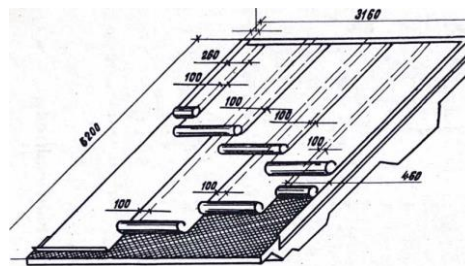


Fig. 1. Layout example of roofing felt for a two-layer waterproof roofing panel

It is allowed to make up the roofing felt in length from two pieces with an overlap of at least 100 mm. The overlap stagger along the width of the lower and upper roofing felt panels should be at least 300 mm (Fig. 2).

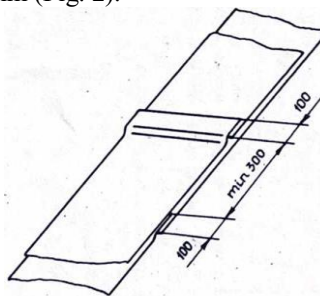


Fig. 2. Arrangement of overlaps of roofing felt sheets in adjacent layers of waterproofing carpet

Work on installing a two-layer waterproof roofing with the help of a solvent on reinforced concrete panels is performed by a brigade of two thatchers of at least grade 4. The main labor costs are shown in table 2.

Table2. Calculation of labor costs may change while improving technology and the tools and mechanisms implemented

Substantiation	List of works	Unit of measure	Time rate per unit of measure, man-hour	Price per unit of measurement, RUB-kop.

House-building plant standards	Gluing the two layers of waterproofing from melted roofing felt on a freshly formed reinforced concrete panel (with cutting of roofing felt)	100 m ²	7.69	4-80
	Double rolling of an uncooled roll flooring with a 100 kg roller		1.0	0-6C
	Total		8.69	5-40

Table 3. Quality control of operations is shown in Table. 3. The quality is checked by the foreman.

List of controlled operations	Control subject	Control methods	Control period
Gluing roofing felt sheets on a freshly formed panel	Overlap of the bottom layer of the waterproof roofing	Measuring with a ruler	Before gluing the top layer of waterproof roofing
Gluing roofing felt panels to a freshly formed panel	Overlap of the upper layer of the waterproof roofing Gluing accuracy	Measuring with a ruler Visual analysis	Before steaming in a steaming chamber During operation (layer by layer)
Roofing treatment using a 100 kg roller	The presence of bubbles, blisters, detachment of the first layer of waterproof roofing from the concrete surface, 100 mm wide along the contour of the panel	Ditto	Ditto

The need for basic materials and semi-finished products is shown in Table 4.

Table 4. Basic materials and semi-finished products

Item	Type	Unit of measure	Quantity for 100 m ² of panel
Melting roofing felt according to TU 21-27-35-78	PM-500-2.0 or PM-420-1.0	2	115.0
Solvent		t	0.02

The demand for tools and equipment is presented in Table 5.

Table 5. Demand for tools and equipment

Item	Quantity
Roller for solvent application Smoothing rabble for roofing felt	2
Roller weighing 100 kg for roofing rolling	1
Kerosene canisters	2
Roofing knife	
Tape measure RZ-420 GOST 7502-69	1

500 mm long metal ruler GOST 427-75	1
-------------------------------------	---

Occupational safety. When installing a roll-up water proofing made of melting roofing felt with the help of a solvent, the requirements of occupational safety in construction should be followed. These are part 1 and part 11 of "Fire safety rules during welding and other hot work at national economy facilities"; "Fire safety rules during construction and installation works".

Persons at least 18 years old who have passed a medical examination are allowed to perform the installation of a waterproof roofing made of melting roofing felt on panels. It is prohibited to involve teenagers and pregnant women in the operation.

Regardless of the production experience, roofers must undergo an introductory (general) briefing on occupational safety, as well as job instruction directly at the workplace.

The solvent should be stored in metal drums with a capacity of 200 liters at a distance of at least 2-3 m from buildings. Solvent, which is required for the shift, must be stored in metal cans of 20 liters. The canisters are stored in a container that prevents them from tipping over. The lids must be closed.

Filling canisters from drums should be performed with a hand pump.

Application of solvent to the roofing melt with a brush or a roller from a supply container with kerosene is produced using the amount necessary for the installation of a rolled roofing on one panel.

Places for draining, pouring and applying the solvent to the roofing material should be kept clean, spilled solvent should be removed, and the spill spots should be covered with sand, followed by cleaning

It is forbidden to work in greased clothing and smoke at the workplace. The used cleaning materials, as they accumulate, must be put into metal boxes with tight-fitting lids and removed from the workplace at the end of the shift.

Empty containers from under the solvent should be stored in a specially designated area in a closed state, apart from the workplace in accordance with requirements of current fire safety regulations.

It is forbidden to repair (weld, solder, rivet, etc.) metal containers from under the solvent before washing and degreasing.

Roofing felt must be stored in a special warehouse and delivered to the production site no earlier than a day before application.

Locations for operating and storing the kerosene must be provided with a portable fire stand and also with the following fire extinguishing and medical assistance equipment:

foam fire extinguishers - 2 pcs.

boxes with sand 0.5 m³ - 1 pc.

shovels - 2 pcs.

fire-resistant cloth -1m

first aid kit with a set of medicines - 1 pc.

The use of firefighting equipment for household, industrial and other needs not related to the training of fire brigades and firefighting is strictly prohibited.

When operating with a solvent in the area of roofing installation, it is not allowed to perform operations using open fire and sparking. For operations with solvent it is necessary to organize workplace ventilation.

The roofing installation area must be marked with signs warning of caution and prohibiting the use of open fire. In the work area, "No Smoking" posters should be displayed.

In case of fire, the actions of the manufacturer's administration and the head of the fire brigade should be aimed at ensuring safety and evacuating people above all.

Every worker or office employee who detects a fire is obliged to act as follows:

- a) immediately report this to the facility or fire department by calling "01";
- b) start extinguishing the fire with the existing equipment available at warehouse or at a workplace;
- c) take measures to callout the workshop manager, foreman or other official to the place of fire.

The air in the working area must comply with sanitary and hygienic requirements in accordance with GOST 12.1.005-76 Occupational Safety Standards System (SSBT). Work area air. General sanitary and hygienic requirements. The following personal protective equipment should be used while gluing roofing felt using solvents:

- clothes of the NT subgroup in accordance with GOST 12.4.015-76. Occupational safety standards system. Special clothing. Classification.;
- special mittens type E in accordance with GOST 12.4.010-75. Interstate standard. Occupational safety standards system, personal protective equipment;
- leather footwear of group O according to GOST 12.4.017-76 Occupational safety standards system. Special leather footwear. Classification. Update date: 02/01/2020;
- respirators of the RPG-67A brand in accordance with GOST 12.4.004-74 - Filter respirators, gas mask. Technical conditions.

4. Discussion

The development of the main sectors of the national economy in Russia and the CIS countries is associated with the construction of new and modernization of existing industrial and civil buildings and structures of various design schemes. This development vector could be observed according to the state programs adopted within the last decade. The special group in the total volume of new construction and reconstruction of buildings and structures consists of buildings and structures with high-prefabricated roof coatings made of rolled materials.

These are housing and civil, public, industrial buildings, one-story and multi-story with a reinforced concrete or metal frame. In addition, these are trade and shopping and entertainment buildings with a frame made of lightweight structures (medical, sanatorium, sports buildings and complexes, low-rise and multi-storey residential buildings). The racks (columns) of the frame in such buildings are located at various distances from 1.5 to 6 meter laterally. It is economically and technically feasible to use prefabricated coating panels in roof structures for such constructive schemes, which makes roofs more reliable and durable. In addition, part of the work is carried out at the factory, which makes it possible to reduce construction and installation work at the construction site.

Suggested organizational and technological solutions allow carrying out the technological processes proposed in the work production project with high quality and safety, if all the requirements are met. They also allow reducing the labor intensity and energy consumption and increasing the level of labor mechanization.

The above-mentioned technology has been tested in practice numerous times [1, 2, 3, 4, 6, 11], the assessment of technological methods was carried out by expert methods. Expert assessment methods are quite widespread in research and allow making decisions and drawing conclusions on various aspects. The popularity of this methodology is due to several factors. Firstly, it is the possibility of obtaining quantitative indicators using qualitative data as input. Secondly, the possibility of obtaining estimates based on the analysis of multiple factors, which are very difficult to evaluate mathematically. Thirdly, the simplicity of the methodology in comparison with the creation of economic and mathematical models for decision making. This is because not all managers possess knowledge regarding creation of mathematical models and have enough time to fully and

independently analyze the issue. The expert analysis procedure has been extensively developed, well-grounded and formalized as much as possible.

According to the methodology proposed in, the optimal number of experts was determined. The experts were asked to fill out a questionnaire consisting of 33 questions to find the optimal method to compensate for the missing information. Thus, in order to obtain a result with maximum consistency of expert opinion, it is necessary to involve 20 experts.

The questionnaire was used to determine the most effective organizational and technological solutions for the installation of prefabricated roof coatings from rolled materials according to experts. It consisted of questions related to the experience of experts, their general construction rating. The questions were also related to their readiness for studying the development and decision-making processes for main design solutions regarding in stallation of roofing from prefabricated roll materials. Information was obtained on the skills possessed by the experts, including the main design solutions adopted by the experts, or those solutions that are possible without large time and material costs. The most important questions raised in the questionnaire are the most effective methods of solving the problem of increasing labor productivity during the roofing works.

Thus, the following survey results were obtained, which showed the effectiveness and appropriateness of using the above methods and techniques.

Studying the problem of the development and adoption of organizational and technological solutions for the **installing the prefabricated roof coatings from rolled materials** led to the adopted hypothesis. According to it, it is possible to develop a model, which will help to simplify the decision-making process for main design solutions. In this case the unplanned costs, both time and material, will significantly decrease due to process optimization.

The conclusions and recommendations made are intended for developers of organizational and technological documentation, including flow diagrams, material statements, regulations, sets of rules [1, 2, 3, 4, 5, 6, 10, 11].

5 Conclusions

The present research is relevant since it most fully represents the technology and organization of roofing works.

Based on the analysis of certain types of technological operations, conclusions were drawn about the need for reducing the use of hand tools for roof installation. It is suggested to switch mainly to mechanized labor in the future.

References

1. V.V. Kucherzhenko, V.M. Lebedev, *Texnologiyai rekonstrukciya zdanij I sooruzhenij* (Moscow, Izdatel'stvo ASV, 2007).
2. B.F. Shirshikov, M.N. Ershov, *Rekonstrukciya ob`ektov. Organizaciya rabot. Ogranicheniya. Riski* (Moscow, Izdatel'stvo ASV, 2010).
3. M.V. Berlinov, *Osnovaniya I fundamenty* (Moscow, Izdatel'stvo Lan', 2011).
4. S.A. Sinenko et al., *Osnovy` normativnoj bazy` v stroitel'stve* (Moscow, Izdatel'stvo ASV, 2016).
5. B.F. Shirshikov et al., *Organizacionno-texnologicheskie resheniya po bezopasnosti truda v proektax proizvodstva rabot* (Moscow, Izdatel'stvo ASV, 2015).
6. M.N. Ershov et al., *Proizvodstvo krovel`ny`x rabot I ustrojstvo zashhitny`x pokry`tij* (Moscow, Izdatel'stvo ASV, 2016).

7. P.P. Olejnik, B.F. Shirshikov, *Sostav razdelov organizacionno-texnologicheskoy dokumentacii I trebovaniya k ix sodержaniyu* (Moscow, Izdatel'stvo MGSU, 2013).
8. B.F. Olejnik, V.I. Brodskij, *Organizaciya stroitel'nogo proizvodstva. Podgotovka I proizvo stvo stroitel'no-montazhny`x rabot* (Moscow, Izdatel'stvo MGSU, 2014).
9. S. Sinenko et al., IOP Conference Series: Materials Science and Engineering **753** 042012 (2020). doi:10.1088/1757-899X/753/4/042012.
10. O. Salosin, IOP Publishing **1614** 012028(2020).doi:10.1088/1742-6596/1614/1/012028.
11. L.A. Demidova et al., *Prinyatie reshenij v usloviyax neopredelennosti* (Moscow, Goryachayaliniya, Telekom, 2015).