

Drainage material produced from roofing waste

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Abstract. As of today, the development of energy efficient and recycling technologies seems to be urgent. This article considers the problem of recycling of wastes in roofing industry, which is a serious environmental contamination source and creates a significant fire hazard. We have made an attempt to create a new drainage material from roofing waste. This material has the appearance of fibrous board, which is made of trimmings of bitumen-impregnated roofing roll materials thermally bonded in contact points. The technological scheme of the producing of the material was developed. The material was tested to determine its physical and mechanical properties (tensile and compressive strength, water permeability and porosity) and to optimize its technological parameters. According to the results of the experiment it was founded that the material has sufficient physical and mechanical properties, meets the technical requirements for drainage materials and can be recommended for use in underground construction.

1 Introduction

Currently, during the construction and operation of residential buildings and industrial structures, underflooding of basements is often observed. Sources of underflooding can be groundwater and surface waters, as well as leakage from communications [1].

Typically, the protection of underground structures against underflooding provides waterproofing combined with wall and circular pipe-draining. However, existing protective structures do not always provide reliable protection of structures from groundwater [2].

More often drainage boards made of filtration materials are used as wall drainage: filtration concrete, filtration expanded polystyrene, etc. (Figure 1a). Filtration concrete has an open porous structure, due to the fact that the binder, enveloping the grains of aggregates, leaves space between them, providing filtration of water. But such boards have some drawbacks: a large mass, brittleness, laboriousness during installation. Filtration expanded polystyrene have a low mass, high filtration coefficient, resistance to aggressive groundwater. However, when the depth of the deposit increases, its water-carrying capacity significantly reduces, the surface layers are filled with soil, which reduces the efficiency of the boards by 30-80% [3-8].

In recent years, wall drains in the form of single- and multi-layered plastic membranes with rounded spines have become widespread, for example, Delta Drain, Planter, etc. (Figure 1b). They have a high mechanical strength, stability to various chemically aggressive substances and resistance to biocorrosion, are able to withstand the load from

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the backfill soil to 0.05 MPa, and convenient for transportation. Plastic waterproofing membranes have some advantages over drainage boards, but they are quite rigid, which makes it difficult to perform overlap joints, because it requires using special mastics to better bond joints. In addition, they have a high cost [9-12]. The materials are not always effective, it is difficult to utilize them and they are a serious source of soil and environmental pollution.

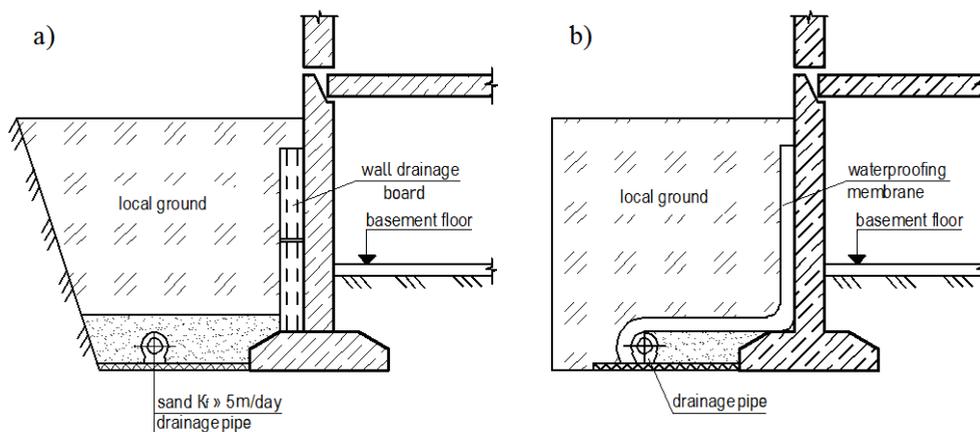


Fig. 1. Scheme of a waterproofing system: a) using wall drainage board; b) using waterproofing membrane

According to the world trends of development of the construction materials industry and the concept of sustainable development, the priority directions are the development of energy-efficient technologies, and the involvement of waste in production.

Every year, just one roofing factory generates more than 7.5 thousand tons wastes. They are bitumen-impregnated trimmings of synthetic and glass fabrics of small dimensions and indefinite shape. The wastes belong to the IV class of danger, it is difficult to utilize them because of their shape and size, and to destroy, because they do not decay and can persist for a long time, and to burn them is extremely problematic because of the high bitumen content. Therefore, around each plant that produces rolled roofing materials, huge mountains of waste are formed, which pollute the environment and create a significant fire hazard.

2 Experiment

We have made an attempt to develop a drainage board material, formed by the thermal bonding of trimmings of roofing waste products according to the following technological scheme.

Wastes in the form of trimmings of bitumen-impregnated roofing roll materials are delivered by an electric loader to the receiving belt conveyer, which transports them to a cutting machine, where they are ground to fibers with a width of 0.8-2.2 mm.

Thereafter, the material is conveyed by a scraper conveyer into a bunker equipped with an agitator. By the screw conveyer it enters to a twin-screw reactor-mixer, where the material is stirred while heating to 130-140°C. During the process, bitumen begins to melt and bonds the fibers together in contact points. Then the material proceeds to the rollers by a belt conveyer-cooler where the mass is plasticized by passing through the gap between the rolls. After achieving the necessary degree of plasticization, the mass is cut with a special knife in the form of a tape.

The final stage of mass processing is performed on a roller calender. The function of the calender is to form a continuous tape of material of the required thickness and width. The thickness of the material is determined by setting the gap between the last two rolls of the calender. Next, the drainage material is packed and transported to the warehouse.

The technological scheme of production of drainage boards produced from roofing waste is shown in Figure 2.

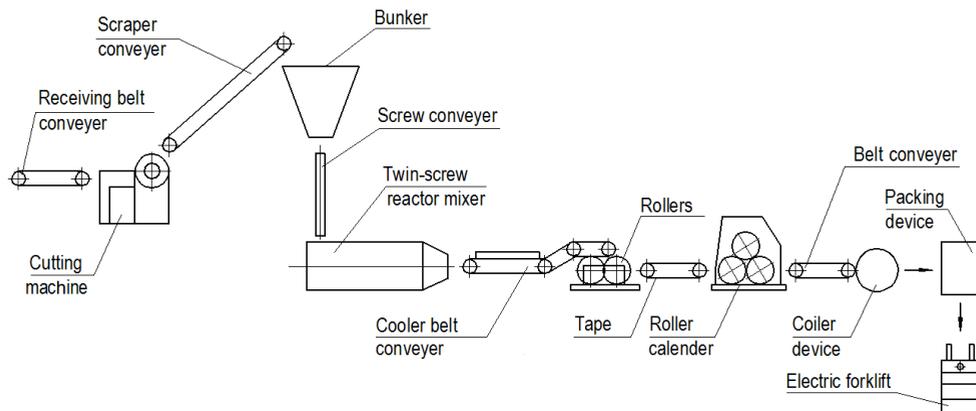


Fig. 2. Production technology of the drainage material by recycling roofing waste

3 Results of the study of physical and mechanical properties

During the development of a new drainage material technology, the influence of various technological factors (temperature, mixing time and fiber width) on the physical and mechanical properties of the material was studied: mechanical strength, water permeability and porosity.

Two series of samples were made: with a fiber width of 0.8-1.0 mm and 2.0-2.2 mm (Figure 3).



Fig. 3. Samples of drainage material: a) fiber width 0.8 - 1.0 mm; b) fiber width - 2,0 - 2,2 mm

The tensile strength was determined in accordance with GOST 11262-80 [13].

Based on the obtained results, it was found that the tensile strength of the material increases significantly with increasing temperature and mixing time. This is due to the fact that bitumen is more intensively releases from the material and firmly bonds the fibers together. So, the tensile strength varies between 0.4-0.8 MPa depending on the temperature

in the range of 100-200°C and the mixing time from 5 to 40 minutes. This is quite sufficient for the application of the material as wall drainage [3, 5]. Moreover, it was found that when the fiber width increased from 0.8 to 2.2 mm, the strength of the material decreases by 26-29% (Figure 4).

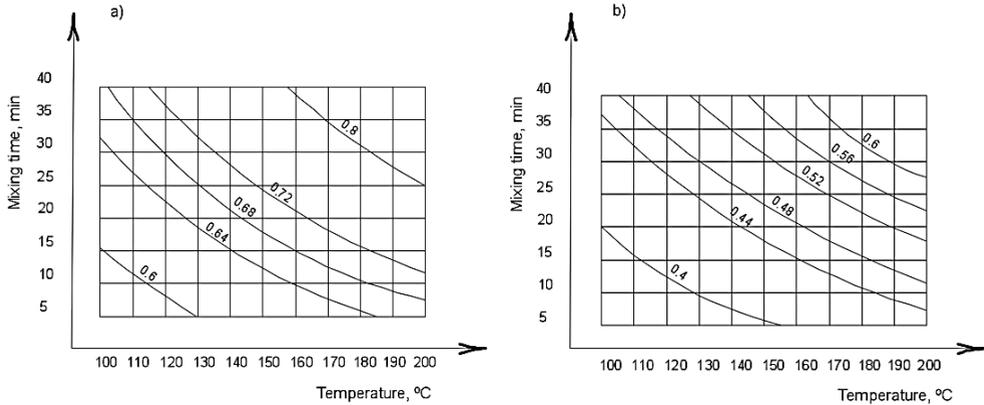


Fig. 4. Dependence of the tensile strength on temperature and mixing time of the drainage material with fiber width: a) 0.8 mm; b) 2.2 mm

The most important criteria for assessing the quality of drainage materials are their open porosity and water permeability.

The device shown in Figure 5 was used to determine water permeability (the filtration coefficient).

The filtration coefficient was determined as follows: the device was pressed to the sample and filled with water ($V = 0.5$ liters); the stopwatch was turned on at the same time, and the time for emptying the tank was measured. The test was carried out at least three times in different parts of the sample.

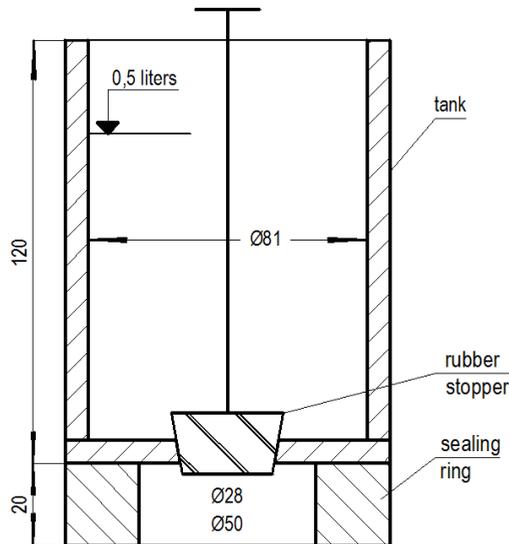


Fig. 5. Device for determining the filtration coefficient

The filtration coefficient of the samples (K_f , cm/sec) was calculated by the formula (1):

$$K_f = \frac{H}{T} \tag{1}$$

where K_f – filtration coefficient, cm/sec; H – height of a water column, cm; T – emptying time, sec.

$$H = \frac{V}{\pi \cdot R^2} \tag{2}$$

where V – cylinder volume, cm^3 ; R – cylinder radius, cm.

As the filtration coefficient is a small value, for the convenience of calculations, a unit is m/day ($0,01 \text{ m/sec} = 86,4 \text{ m/day}$).

The porosity of the material was determined as follows. First, the total volume of a dry sample with pores was calculated. Then it was placed in the cylinder with water. The volume of the displaced water was determined by the volume of the sample. Further, according to the formula (3), the pore volume in the material (P , %) was calculated:

$$P = \frac{V_1 - V_2}{V_1} \cdot 100 \tag{3}$$

where P – porosity of the material, %; V_1 – volume of a dry sample with pores, %; V_2 – matrix volume (displaced water volume), %.

Based on the obtained data on porosity and water permeability, it was found that the width of the fiber had a great influence on the porosity and water permeability. When the width of the fiber decreased, the amount of pores and their size in the material increased, and therefore the water permeability became higher. However, the increase of the temperature and the mixing time adversely affected the porosity and, accordingly, the water permeability of the material. This is due to the fact that bitumen, which was released more intensively with increasing temperature, fused the material, which prevented the formation of pores. As can be seen from the graphs (Figure 6, 7), the filtration coefficient, depending on the temperature in the range of 100-200°C and the mixing time from 5 to 40 minutes, ranges from 100 to 250 m/day, and the porosity is from 25 to 50%.

The obtained data testify to the high water permeability of the material, which meets the requirements for filtration materials used as a wall drain (more than 10 m /day) [4].

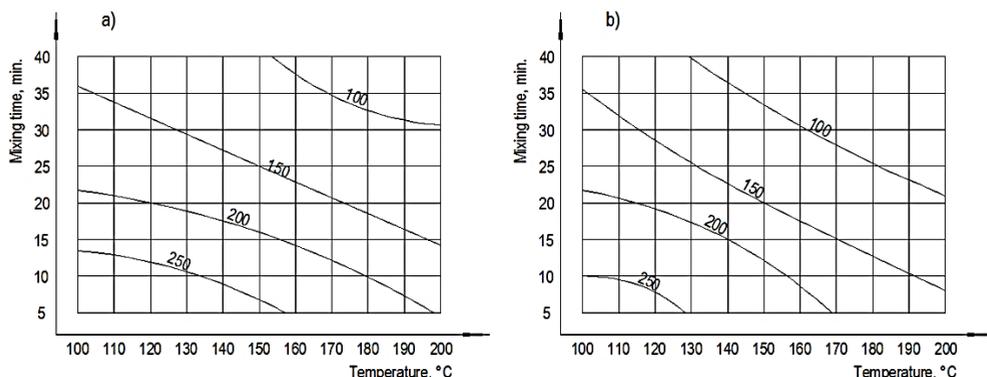


Fig. 6. Dependence of the filtration coefficient on temperature and mixing time of the drainage material with fiber width: a) 0.8 mm; b) 2.2 mm

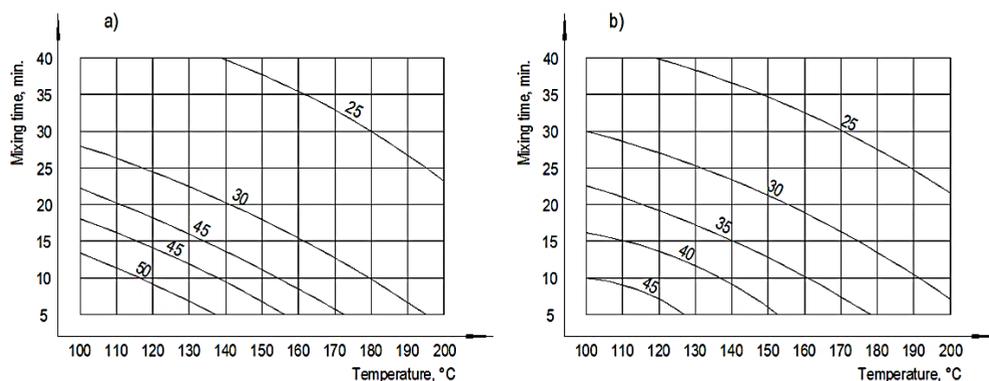


Fig. 7. Dependence of porosity on temperature and mixing time of the drainage material with fiber width: a) 0.8 mm; b) 2.2 mm

The compressive strength at 10% linear deformation was determined in accordance with GOST 15588-2014 [14]. The data obtained in the test samples ($f_c = 0.2-0.4$ MPa) indicate the possibility of using this material, taking into account the lateral pressure of the soil on the underground wall, depending on the depth of the foundation and the type of soil (Table 1) [3].

Table 1. Lateral pressure of different types of soils on the underground wall, depending on the depth of the foundation

Soils	Depth of the foundation, m				
	3	5	6	7	8
Fine sand	0,014	0,023	0,028	0,030	0,037
Sandy loam	0,020	0,330	0,040	0,046	0,053
Loam	0,023	0,040	0,045	0,053	0,060
Clay	0,031	0,051	0,062	0,072	0,082

Using the mathematical methods of experiment planning, the following optimized technological parameters were established:

- material mixing temperature (t°) 130-140°C;
- mixing time (τ) 20-25 min.;
- fiber width (b) 0,8-1,0 mm.

Table 2 presents the comparative physical and mechanical properties of the developed material with drainage boards made of filtration concrete and filtration expanded polystyrene.

Table 2. Physical and mechanical properties of drainage boards

Property	Drainage boards		
	Filtration concrete	Filtration expanded polystyrene	Material based on roofing waste
Compressive strength, MPa	2,5-10	0,08-0,14*	0,2-0,4*
Tensile strength, MPa	-	-	0,4-0,8
Porosity, %	10-25	10-30	25-45
Filtration coefficient, m/day	50-100	50-150	100-250

* Compressive strength at 10% linear deformation

4 Conclusion

The development of a new drainage material makes it possible to solve three main problems: ecological, engineering and economic. The results of the investigation show the possibility of creation a drainage material by recycling of roofing waste. First of all it can decrease environmental contamination and fire hazard near roofing producing plants and improve the ecological situation. Moreover, the results of the tests demonstrate the sufficient strength, high water permeability and porosity of the new material, meets the technical requirements for drainage materials. And finally this material is cheaper than its analogs because it is made of wastes. Summing up all the above, we can recommend it for using as wall drainage in underground construction.

All tests were carried out using research equipment of The Head Regional Shared Research Facilities of the Moscow State University of Civil Engineering (RFMEFI59317X0006).

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