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Using solid household plastic waste in the construction of soil embankments

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Abstract. The article analyzes innovative ways of using crushed solid plastic in a mixture with soil for arrangement of soil embankments for various purposes. Using a mixture of loam loess and crushed plastic, on the one hand, solves the environmental problem of plastic recycling, and on the other hand, creates technological material for the erection of the embankment. In order to determine the suitability of the material, laboratory studies of the characteristics of the mixture were carried out. For each sample of the mixture, the optimal humidity and density of the skeleton were determined by dynamic compaction in the MDU-1. The modulus of deformation of the compacted specimens is determined. The article investigates the characteristics for the composition of the loam loess and crushed plastic containers in the ratio of 80:20 %.

1. Introduction

An immediate problem is the recycling and reuse of waste. Solving the problem will create new businesses and improve the environmental status of the regions. Waste recycling for profile industries significantly saves on the consumption of polymeric raw materials and electricity. Processing of plastic waste contributes to the increase of manufactured products without additional investments for the purchase of raw materials. In some countries, up to 90 % of household and industrial waste is recycled. In Ukraine, much less plastic is recycled.

The growth of construction is stimulating the tendency to intensify the reconstruction of infrastructure and urban improvement. This tendency makes the task of developing economical soil embankments with high operational qualities especially relevant. The embankments must have such properties as to permit year-round construction [1].

In many regions of Ukraine there are considerable reserves of mineral materials which, after special treatment with organic and inorganic binders, can be effectively used in the construction of road bases, embankments.

Compositions with the use of industrial waste are increasingly used to save materials when arranging layers of bases, embankments. By-products and wastes from various sectors of the economy are introduced as additives and reagents. They increase the construction and technical properties of the processed materials. Such technologies of bases construction of covering roads, embankments simultaneously solve a problem of waste recycling.

In our country, only the garbage disposal industry is emerging. Only 5.6 % of all waste is sorted. According to the United Nations, more than 13 million tonnes of plastic are released into the oceans



annually, destroying native flora and fauna. It takes more than 100 years to decompose plastic waste. Dioxin is released when burning plastic bottles. Landfills across the country have collected more than 300,000 tonnes of this type of waste, although it can be recycled. Plastic waste is now used for the manufacture of other plastic products. When recycled without pre-sorting, plastic waste is crushed, impurities are separated, granulated and further used for the production of containers, bedding, souvenirs, toys and the like.

Waste processing gives valuable raw materials for the production of secondary commodity products. It is economically feasible if the cost of the products obtained exceeds the cost of disposal [2].

A.V. Lisyannikov (2017) proposes to use plastic waste in the construction of roads. He gives examples of the use of plastic in the construction of highways in the world. Cases of plastic use are known for road construction. The remnants of plastic containers are mixed with bitumen and used for the manufacture of semi-flat materials for laying the road [3]. The first Jambulingam Street plastic road, built in 2002, is already in operation. Such a road, without significant destruction, has endured countless floods, monsoons, constant heat exposure and a continuous flow of cars and trucks [4]. However, the use of plastic waste as an embankment or as a road base has been investigated less. According to the authors, this area is also noteworthy.

The main purpose when using plastic in the construction of embankments is:

- 1) Solving the problem of accumulation of plastic waste.
- 2) Reduce the cost of building roads and embankments.
- 3) Introduce new materials and technologies for the construction of roads and artificial structures.
- 4) Improve the environmental status of the environment [5].

When constructing embankments for the treatment of mineral materials, scarce and relatively expensive binders are advisable to use in minimal amounts. In this case, it is necessary to investigate the possibility of using a mixture in the construction of embankments, where some of the waste from plastic containers.

The purpose of the article is to propose ways to recycle plastic garbage as a resource-saving technology in the construction of embankments. To substantiate the technological solution for the use of plastic debris when mixed with the soil of the construction site when arranging embankments [6].

2. Methodology and research

An embankment is an artificially constructed section of a dike (dams, etc.) within which the main site is located above the surface of the earth. In cohesive soils this way arrange the earth cloth of roads and railways, earth dams and dams, jumpers, sites for some industrial objects, etc. At small volumes of an embankment (an earthen canvas with calm terrain) the soil is poured out after transporting it from special ditches-ditches or reserves (extended ditches) located along the embankment. With large volumes of embankment (rough soil in rough terrain, dams, etc.), soil is taken from recesses of large sizes and soil quarries.

The embankments must meet certain requirements for the composition and characteristics of soils, stability, density and water resistance.

The soil embankment serves as the basis for the upper part of highways and railways. Its strength and durability are ensured by observing the required slope, which depends on the height of the embankment or the depth of the recess, the type of soil, the level of groundwater and the methods of laying the soil.

In road construction, the base layers have the greatest thickness. Therefore, their construction is associated with a high cost of construction materials. At the same time, the layers of bases, embankments work in more favourable conditions when compared with coatings. This allows for the extensive use of local materials and industry waste for embankment construction. The expediency of using plastic waste is justified by feasibility studies, taking into account the possible shortening of the service life compared to the use of standard materials [7, 8].

The authors propose to use as a mound material consisting of loess loam and crushed plastic containers. The use of plastic in the construction of embankments is justified by the cost savings on the disposal of huge waste heaps [1].

The authors investigated the characteristics of a mixture of crushed plastic waste and loam of natural moisture (Figure 1).



Figure 1. General view of the components of the mixture: 1 - loess loam; 2 - crushed plastic waste (2 mm).

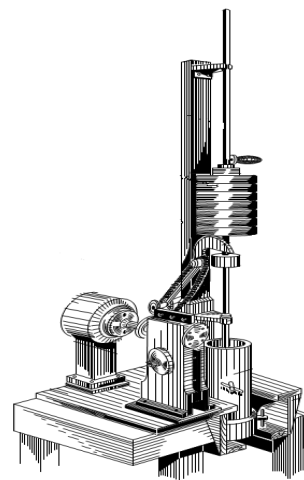


Figure 2. Stationary mechanized device for dynamic soil compaction of MDU-1

For research, loess loam was selected from a depth of 2 m. The average humidity of soil samples in determining the natural humidity was about 25 %. Its humidity on the verge of fluidity is 35 %, humidity on the verge of rolling is 19 %. The study was performed according to standard laboratory methods of soil research according to DSTU B.V.2.1-17: 2009 [9]. For the study of the mixture, which is offered as embankments, wastes plastic fraction up to 2 mm.

For further analysis, select the mixture at a loess loam and crushed plastic containers in the proportion of 80:20 %. The studies were performed according to the standard soil compaction technique [10]. The study used a stationary mechanized device for dynamic soil compaction of MDU-1 (Figure 2).

The design of the device MDU-1 consists of a base plate and gearbox, electric motor, rack with brackets, the rod on which the weights move. The drive design is made of two pivotally connected rods. This design maintains a constant drop height of the weight in the process of sealing the sample. A variable form is attached to the plate. Samples from a mixture of loess loam and crushed plastic containers were made with a diameter of 10 cm and a height of 12.7 cm.

For the experiment, 6 samples of the appropriate size were made. Dynamic soil compaction is as follows. A certain amount of water is added to the soil sample at humidity W_0 to obtain samples of optimal humidity. A sample of the soil mixture was placed in a thin layer on the bottom of the tank and moistened evenly with a laboratory burette. With this method, moisture in the soil was distributed evenly. The soil was thoroughly mixed and filled into a pre-harvested and oiled glass of the MDU-1 (Figure 3). The stirred and moistened mixture was kept in the hydrator for about 2 hours in order to distribute moisture evenly. The mixture was poured into a glass of steel from a height of about 10 cm. The height was the same for all samples. Prior to sealing, the specimen was compressed for several

minutes with a static load of 10 kg. This was done to reduce macro pores and air voids. The initial humidity of the samples was more than half the humidity at the boundary of plasticity. Since the humidity of the samples is less than this value, the sealing of the samples will be less effective.



Figure 3. General view of the steel glass of the MDU-1.

Experiments on dynamic compaction of the samples were carried out at equality of initial height of the samples. Therefore, before compaction with a depth gauge, the soil level in the glass of steel was checked. After the soil compaction is completed, the mass of the glass of steel with soil is determined to the nearest 1 gram and two samples are taken to determine the humidity. Then a steel beaker with a prepared soil sample was mounted on the base plate of the device MDU-1. The deformation of the soil in the course of the experiment on the instrument MDU-1 is measured with a depth gauge from the top of the glass after each stroke with the number of strokes up to 10. The experiment was stopped if the deformation difference during the last 5 to 10 strokes would be less than 0.5 mm.

With these characteristics, samples of the compacted mixture were made to evaluate its compressibility in the compression device [10].

According to the results of the compression tests, the modulus of deformation was $E = 28$ MPa. Therefore, the modulus of deformation of the mixture was determined at optimal humidity $W_{opt} = 0.15$ and $\rho_{d\ opt} = 1.67$ g/cm³. What can be considered sufficient to use a mixture of loam and crushed plastic as an embankment [11, 12].

3. Conclusions

1. The proposed method of disposal of plastic waste by using it in the composition of soil embankments. The use of plastic in the construction of embankments is justified by the cost savings on the disposal of huge landfills of plastic waste.
2. Preliminary studies of the sealing of such mixtures in laboratory conditions using the MDU -1 device have been carried out. The obtained values of the optimal humidity of the mixture $W_{opt} = 15$ % and the optimum density of the mixture $\rho_{d\ opt} = 1.67$ g/cm³. According to the results of previous compression tests, the modulus of deformation of the compacted mixture was $E = 28$ MPa. That is, we can conclude that recently there have been promising innovative directions for the use of recycled plastic in the construction of embankments. When using a mixture of loam loess, crushed plastic with a fraction size of about 2 mm, it is possible to solve the environmental problem of recycling plastic household waste.

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