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The effect of lime admixture to trench backfill on the functioning of drainage

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Abstract

The study examines the effect of lime admixture to trench backfill on the functioning of tile drainage after almost 25 years of operation. The hydrosystems' efficiency examination was performed at the test site in Kalnujai, Raseiniai District, where filtering capacity of drainage trench backfill had been improved by lime admixture. When analysing the maximum drainage discharge per unit length at the control drainage systems as of spring and autumn of 2012 (0.250 and 0.288 ml/s m respectively), as well as the drainage discharge per unit length as of spring and autumn (0.297 and 0.392 ml/s m respectively) in the drainage, where the trench backfill filtering capacity had been improved with lime admixture (0.6 % of the soil mass), correspondingly 15.2-31.9 % better results were obtained. When evaluating the drainage systems efficiency indicators as of 2003 and 2012 with the 95 % reliability, it can be stated that the efficiency of drainage, where the filtering capacity has been improved with lime admixtures, remained virtually unchanged after almost 25 years of operation.

Keywords: drainage; trench backfill liming; drainage discharge.

1. Introduction

Lithuania is located in a zone of excessive humidity. The country's soils intended for agriculture are most often too damp; therefore, drainage hydrosystems form a very important part of agricultural production infrastructure. Soil draining is essential: about 90% of the total agricultural output is cultivated on drained soil.

Efficiency of draining sandy loam soil is essentially dependent on the drainage distance, which is mainly influenced by the soil permeability, i. e. its filtering capacity. In case of atmosphere feed, the efficiency of draining heavy loam and clay soils also depends on other drainage elements, such as drainage pipe joints and perforation parameters, hydraulic resistance of the drainage pipes' protective filtering material and filtering capacity of the trench backfill. Some authors [1], [2] are of the opinion that all the essential drainage elements have almost the same effect when draining heavy loam and clay soils.

In the critical drainage systems operation moments, the atmosphere fed water flows into the tile drains of clay soil through a more permeable upper layer and trench backfill or through the spot of contact of trench backfill and inter-tile drain soil, since, due to the soil sedimentation, such locations have cracks [3]. Therefore, when draining soils of heavy mechanical composition, a very important indicator is the drainage trench backfill water permeability. In such soil the infiltrating water flow resulting from precipitation most frequently gets to the tile drains through the trench backfill, when flowing through the vegetative and more structured soil layer (in extreme meteorological conditions – almost the entire water flow). When operating genetically dense or densitied soil, the deep soil loosening method was used. At present, a biological loosening method would be more efficient, i.e. planting Lucerne or similar plants with deep and wide root system. However, such methods are efficient only in case the water permeability of the drainage trench backfill is not smaller than that of loosened inter tile drain soil. In the Western Europe (the UK, Germany, Sweden, etc.), when implementing drainage in heavy soils, the trenches are filled with washed gravel [4], [5].

One of the methods of improvement of permeability of drainage trench backfill implemented in clay soil is using lime admixture [6]. Upon examining the clay soil samples mixed with shale ashes, which have 15–25% calcium and magnesium oxides, in a complex way, i.e. by using the radiography and thermography methods, it was established that using the shale ash admixtures essentially changes the soil's physical properties for a long period of time which is also evidenced by results of laboratory tests [7]. The necessity of use of lime for improving the drainage trench backfill in clay soils has been emphasized for draining light hollows. The tests of intensity of draining of such hollows by admixing lime into the drainage

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trench backfill performed at experimental sites showed that the groundwater levels in inter tile drains of the hollows, where this method was used, were 20–30% lower than in the reference options [4]. Thus, there is a possibility to commence the agricultural works 4–6 days earlier.

In addition, according to Finnish scientists [8], the lime admixtures used for improving the drainage trench permeability increase the pH of the trench backfill soil up to 11; therefore, such backfill arrests the phosphorus, moving along with the water [9]. In case lime filters (catching drains) are implemented at the edges of the main water discharging gutters at the lower part of inclined fields, the surface water gets to the gutter through the filters and joins together the phosphates existing in the water and prevents them from getting into the gutters. In acid soils, the lime filters reduce the drainage water acidity and the amounts of aluminum, magnesium and iron. When making the lime filters, it is important that the soil and the lime hydrate are thoroughly mixed prior to pouring the soil and lime mixture into the drainage trench in order to ensure a robust soil structure. In order to make a good clay soil structure, the lime must amount to approximately 5% of the weight of the moist soil. Usually, the tile drains, implemented by using tile drain installation equipment, require 10–20 kg of lime hydrate for one straight-line meter of a drainage trench. By performing tests [5–7], the optimum amount of lime, necessary to be mixed with the clay soil of the dug trench, was established. Clay soil's water permeability grows when increasing the amount of lime up to a certain limit, which depends on the amount of physical clay particles (<0.01 mm) in the soil. This method significantly increases the filtering capacity of drainage trench backfill, since it forms permanent calcium hydro-silicates, which become even stronger with time. Other thoughts were also expressed, such as that the efficiency of use of lime substances for improving drainage trench backfill in clay soils, both in terms of filtering capacity and arresting phosphates, reduces with time [8].

The aim of study is to identify the drainage efficiency, when the filtering capacity of the drainage trench backfill is improved with lime admixture.

2. Investigation methods

The investigation of drainage efficiency, when the filtering capacity of the drainage trench backfill is improved with lime admixture, was continued in 2011–2012 at the test site in Kalnujai, Raseiniai District (Fig. 1). The test site was implemented in 1988 which means that the drainage trench backfills, whose filtering capacity was improved with lime admixture, are already 25 years old.

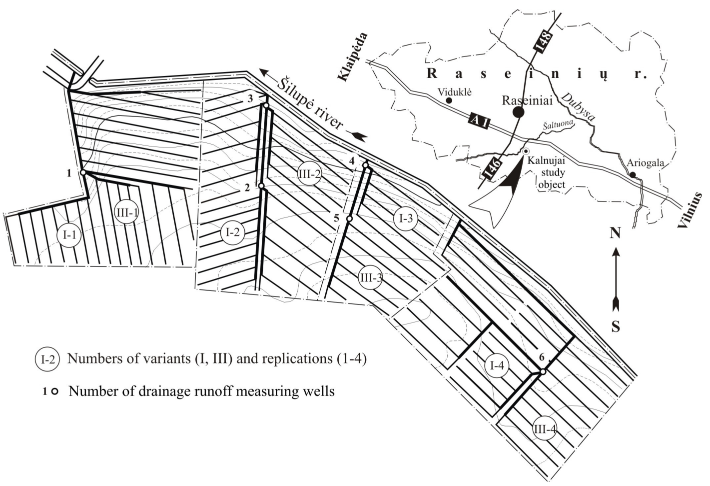

Fig.1 Geographical location and test site in Kalnujai

The filtering capacity of the trench backfills of the drainage, implemented at the Kalnujai site (Fig. 1), was improved with lime admixture. In the Test Option I, the drainage trench backfill was mixed with lime in order for the active CaO to amount to 0.6% of the dry soil mass; in the Control Option III, the drainage trench was filled with local soil, mixed when digging the trenches by a multiscoop ditcher. The drain spacing was 16 m. The options were repeated four times, their areas and the lengths of laid tile drains are provided in Table 1.

When implementing the site in 1988, the chosen lime substance was Estonian shale ashes, widely used at the time and whose activity, in terms of the total amount of CaO and MgO, was 21.5%. The optimum amount of lime A necessary to be mixed with one straight-line trench soil meter is calculated according to the Eqn. (1):

$$A = 500\rho h \frac{0.13 + 0.011N}{n}, \tag{1}$$

where: ρ – soil density g/cm^3; h – the depth of the dug drainage trench m; N – the amount of physical clay particles (<0.01 mm) in the soil %; n – lime activity according to the total amount of CaO and MgO %.

Eqn. (1) should be applied when the amount of physical clay particles in the soil is from 20 to 80% and the width of the drainage trench is 0.5. Upon performing the calculation according to Eqn. (1) it appears that 1 m of the trench will require 24.3 kg of shale ashes. The rounded amount, i.e. 24.0 kg, according to the amount of active CaO and MgO, amounted to

0.6% of the soil mass. The shale ashes were poured on the drainage trench soil by using the lime substance pouring tank with additionally installed cyclone, reducing the speed of pouring and mixed by a special screw bulldozer, which was also used for backfilling the drainage trenches.

Table 1. Test Option in Kalnujai test site (Raseiniai district)

Number of test option	Drainage trench backfill	Number of runoff measurement well	Area of replication, ha	Length of drain, m
I	Mixed with lime (CaO – 0.6 % of ground mass)	1	1.28	544
		2	1.24	612
		4	1.20	676
		6	1.05	552
III (control)	Local mixed soil	1	1.05	572
		3	1.47	788
		5	1.29	648
		6	1.46	708

The drain discharge, measured in the drain discharge measuring manholes, was taken as the main indicator of efficiency of all the options. During the spring and autumn tides the drainage discharge was measured daily, during other seasons – each 2–3 days. The meteorological conditions were evaluated referring to the data, provided by Raseiniai Meteorological Station.

3. Investigation results and discussion

During the time period of study (2011–2012), the tested area was ploughed in autumn, and barley, peas and rapes were sowed in spring. The meteorological conditions varied significantly. The air temperature was insignificantly higher than perennial. The annual amount of precipitation fluctuated from 101.9% in 2011 to 108.4% in 2012. During the vegetation period precipitation fluctuated more significantly – from 113.5% in 2011 to 107.6% in 2012. Even greater difference was observed when analyzing the amount of monthly precipitation – from 46 % of the monthly precipitation norm in November to 223% of the monthly precipitation in July of 2011. According to the data on precipitation of Raseiniai Meteorological Station for the period of 1940-2012, the year 2011 can be classified as a year of average dampness (694 mm) with the 35% precipitation probability. The year 2012 (738 mm) is classified as a damp year with 20% precipitation probability (Fig. 1). When analyzing the precipitation during the vegetation period, i.e. April – October, the conclusion is made that the years 2011 (505 mm) and 2012 (479 mm) were damp and of average dampness with 23 and 33% precipitation probability respectively.

The main climatic factors (precipitation, air temperature) affecting the drainage discharge are continuously interrelated, especially during warm seasons. The larger the amount of precipitation and lower the air temperature, the higher the drainage discharge; the discharge reduces as the air temperature rises, quite frequently even when the precipitation does not reduce, since the air temperature increase results in evaporation of a greater amount of soil moisture [11]. Therefore, the location dampness conditions, in terms of main meteorological factors, are evaluated by the conditional hydrothermic coefficient HTC_s [12]. The values of hydrothermic coefficient HTC_s at the Kalnujai test site during the vegetation period, obtained for the period of 2011-2012, are respectively 1.84 and 1.85. The authors [12] suggest evaluating the location's dampness conditions, in case the values of hydrothermic coefficient HTC_s are ≥ 1.2, as a damp period.

When analyzing the drainage discharge and meteorological conditions at the Kalnujai site for the year 2012 (Fig. 2), it can be seen that the highest drainage discharge have been measured on February 25, when the air temperature rose above zero. In the systems, where the drainage trench backfill was improved with lime admixture (0.6% of the soil mass) and the drain spacing was 16 m (Option I), the drainage discharge reached 0.32 l/s ha. In the systems, where the drainage trench backfill was the control one and the distance between the tile drains was 16 m (Option III), the drainage discharge reached 0.15 l/s ha. The second increase of the drainage discharge in spring was measured on March 24. In the systems, where the drainage trench backfill was improved with lime admixture, the drainage discharge reached 0.17 l/s ha and in control systems – 0.16 l/s ha, which could be explained by the insignificant precipitation during the period and the fact that the spring snow melting water drained away shortly after February 25. Starting from March 24, with the increase of the air temperature, the drainage discharge gradually reduced and in June-July was minimum, notwithstanding that the amount of precipitation, observed in the second ten-day period of July, was more than double (2.2 times) of the norm.

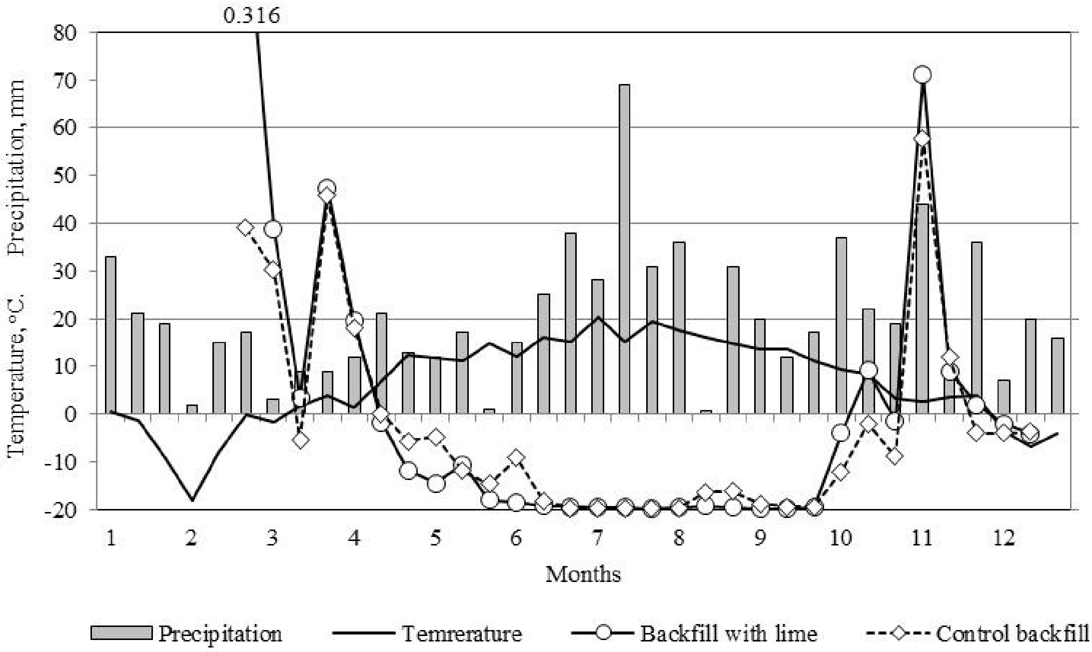

Fig. 2. Precipitation and drainage discharge at Kalnujai test site in 2012

The drainage discharge recommenced in August and September and the maximum value as of the autumn period was reached on November 10, after heavier precipitation in October (1.3 times of the monthly norm). In the systems, where the drainage trench backfill was improved with lime admixture (Option I), the drainage discharge reached 0.23 l/s ha, and in the systems with control drainage trench backfill (Option III), the drainage discharge reached 0.19 l/s ha, which is 1.21 times less than in case of the drainage, where the trench backfill was improved with lime admixture.

According to the data of 2003 [5], at the beginning of the vegetation period, an increase of drainage discharge was measured – the systems, where the drainage trench backfill was improved with lime admixture, the drainage discharge reached 0.22 l/s ha, in control systems – 0.14 l/s ha.

The dynamics of development of drainage discharge per unit length is similar to that of drainage discharge (Fig. 3). On March 24 in the systems, where the drainage trench backfill was improved with lime admixture (0.6% of the soil mass) (Option I), the drainage discharge per unit length s reached 0.297 ml/s m. In the systems with the control drainage trench backfill (Option III), the drainage discharge per unit length reached 0.250 ml/s m. On November 10 in the systems, where the drainage trench backfill was improved with lime admixture, the drainage discharge per unit length reached 0.392 ml/s m, and in the systems with the control drainage trench backfill the drainage discharge per unit length reached 0.288 ml/s m, i.e. 1.36 times less than in case of drainage in the trench backfill with lime admixture.

The drainage discharges per unit length were obtained at Kalnujai test site in 2003 [5–7], at the beginning of the vegetation period (April 14). In the systems, where the drainage trench backfill was improved with lime admixture, the debits reached 0.378 ml/s m, and in the systems with control drainage trench backfill, the drainage discharge per unit length were 0.304 ml/s m.

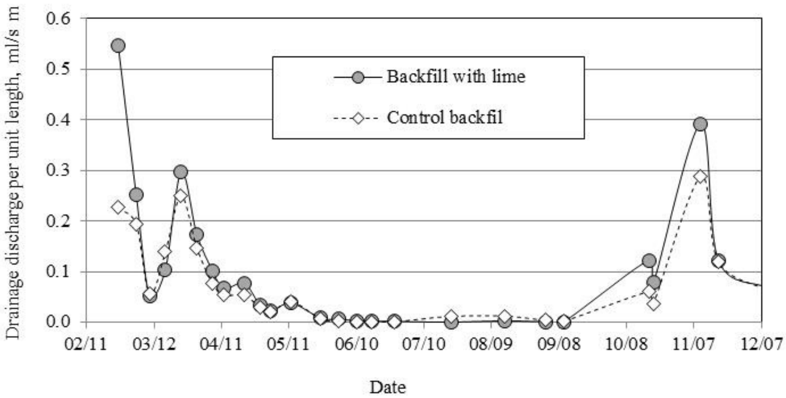

Fig. 3. Drainage discharge per unit length at Kalnujai test site in 2012

As it has already been stated, the test site in Kalnujai, Raseiniai District, was implemented in 1988. When analyzing the maximum drainage discharge per unit length at control drainage systems in spring and autumn of 2012 (0.250 and 0.288

ml/s m respectively) and the drainage discharge per unit length in spring and autumn of 2012 (0.297 and 0.392 ml/s m respectively) in the drainage, where the filtering capacities of trench backfill were improved with lime admixture (0.6% of the soil mass), correspondingly 15.2–31.9% better results were obtained, therefore today, almost after 25 years of operation of the drainage systems, one can state, with 95% reliability, that the drainage efficiency has not reduced.

4. Conclusions

In 2012, the maximum drainage discharge per unit length in the control drainage systems, obtained for spring and autumn, were correspondingly 0.250 and 0.288 ml/s m. In the drainage systems, where the filtering capacity of trench backfill was improved with lime admixture (0.6% of the soil mass), the drainage discharge per unit length in spring and autumn were correspondingly 0.297 and 0.392 ml/s m, or 15.2–31.9% higher.

When evaluating the drainage systems efficiency indicators in 2003 and in 2012, it can be stated with 95% reliability that the efficiency of the drainage where the filtering capacity was improved with lime admixture has underwent no essential changes after 25 years of operation.

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