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Experimental research results on the erosion study of the temporary irrigating canal dam with pouring water and the establishment of the size of the dam compactor's operating body

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Abstract. Research work has been carried out for several years in order to mechanize the technological process of dams' compaction and the development of a dam compactor. As a result of the experiments, the design of the dam compactor and the types of operating bodies were selected, the main optimal dimensions of the dam compactor were determined and mathematically analyzed. It was revealed that the main parameters of the dam compactor affecting the compaction process of temporary irrigating canal dams are cone roller diameter, length and width of the plate compactor, and the angle of dam nip. These parameters have been substantiated by theoretical and experimental studies. The optimal values of these parameters were determined by the mathematical planning of the experiment; below are the limits, as well as the variation levels of these factors. Based on the results obtained, an improved dam compactor was manufactured, and experimental studies were conducted in the field. At the same time, an increase in productivity relative to existing methods has been achieved and the compaction index has been brought to the required value. The mathematical model of the research object is the response function of an equation linking optimization parameters with controlled factors. The hypothesis of variance uniformity in the same non-repeated experiments was tested using the Cochran's test, and the significance of the regression coefficients was determined by the Student's criterion. The adequacy of the process model was checked by the Fisher criterion. After processing the experimental data and evaluating the coefficients' significance, regression equations describing the dam compaction process by the dam height and the compaction degree of the temporary irrigating canal dam were obtained. The main dimensions of compacting operating bodies of the dam compactor were selected.

1. Introduction

The main condition that ensures good growth in the development of agricultural plants is the maintenance of the necessary moisture in the soil, which is provided by vegetation watering. To date, ridge-and-furrow remains the main method of irrigation for agricultural crops. To supply water from a permanent channel to irrigation furrows, temporary irrigating canals are cut with the help of ditchers. When cutting temporary irrigating canals with a ditcher, a certain volume of soil is cut into recesses and poured onto the longitudinal axis from the right and left channels. At the same time, the soil is crumbling at the angle of the natural slope and forms dams.

However, observations of the production process of agricultural crops' irrigation works have shown that the uncompacted dams of the temporary irrigating canals formed by a ditcher are often washed away by water. In addition, the cross-section shape of the temporary irrigating canal dam after the ditcher's passage significantly differs from the shape that is obtained at the time of formation. The poured soil is falling off at the angle of the natural slope, giving the dam's cross section a trapezoidal shape (Figure1).

The general scheme of the formed dam with characteristic dimensions when cutting temporary irrigating canals

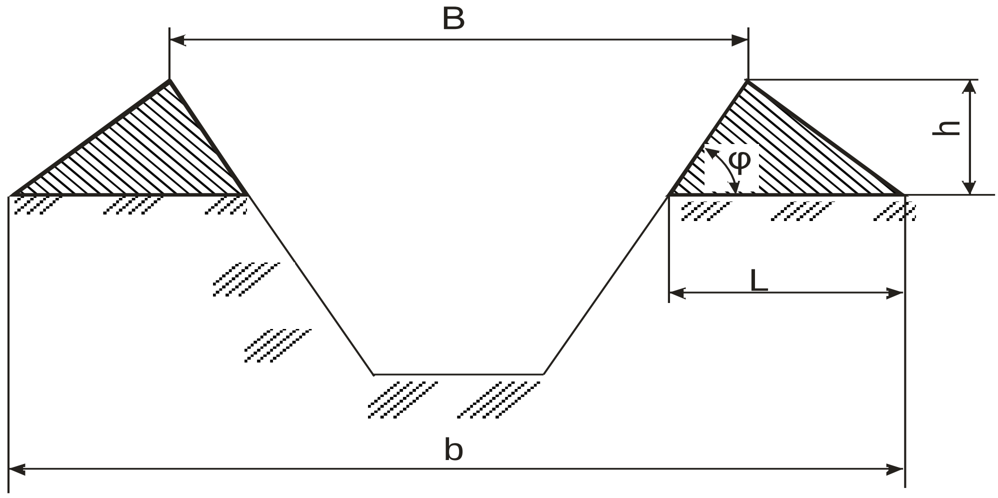

Figure 1. The main dimensional parameters of the dam are correct.

The characteristic dimensions of the temporary irrigating canal dam are the following [1]

1. The total width of the occupied strip of the dam and the temporary irrigating canal - b.
2. The width at the dam base - the distance between the extreme points of the lower base at the field level – L.
3. The width of the upper dam base - B.
4. The production-required height of the dam - the distance between the bases of the dam – h.
5. The slope angle of the dam - φ.

When cutting temporary irrigating canals with a ditcher, rational values of the depth of soil cutting are justified [2]. This requirement determines the occupied strip's width of dams or temporary irrigating canals and the width of the dam along the top, and, therefore, it cannot have a random value.

2. Materials and methods

The filtration process (erosion) of water depending on the soil compaction of the temporary irrigating canal dam was studied. To study the dam erosion in the field conditions of the UzMEI experimental farm, irrigating canals were cut by a ditcher. From the edge of the plot, an auxiliary irrigating canal was cut in a longitudinal direction, on which water flowed with a constant amount. In the perpendicular direction to the auxiliary irrigating canal, experimental canals with a length of 5 m each were cut every two meters. The digging depth of the ditcher was kept constant and equal to 0.18 m. The dam height was within 0.25 m, the width at the base of the dam was within 0.8–0.9 m.

The ends of the experimental irrigating canals were covered with soil. Water was introduced from an auxiliary irrigating canal. The water level was raised 0.15 m above the field level. The water level on the experimental irrigating canal was controlled by a measuring ruler forgotten on the plot.

From the moment the water was put into the irrigating canal, its seepage through the dam was monitored. The average value of the dam soil moisture before water introduction was 16.3–17.2%. Measurements of water filtration through dams were made every 0.25 hours with an accuracy of 0.5 cm. To determine filtration, a cross-section was made on the dam and the area of water seepage was measured with a special quadrangular measuring plate.

The dependences of water filtration on soil compaction were studied since the size of the pores depends on the soil compaction. Micropores, that is, spaces between soil particles occupied by water or air, are present in the soil in any of its conditions and are more stable than macropores formed during processing.

There are different ways to reduce macropores: by compaction, adding sand or binders, reducing the soil fraction, etc. [3].

Compaction of the dam soil by external force was adopted by the authors during further study. Determination of filtration dependence on soil compaction was carried out by varying degrees of dam compaction. The soil density of the dam under the action of compaction varied from 0.9 $g/^{cm3}$ to 1.7 $g/^{cm3}$.

3. Results and discussion

Experimental studies have shown that the soil condition of the dam characterized by a density of 1.5 $g/^{cm3}$, does not allow its erosion (Table 1). Therefore, this condition can be considered the lower densification limit and, in the future, when compacting the associated soil of the dam, it is necessary to achieve these density values. At the same time, the height of the dam decreases and its value should provide a command water level.

Table 1. Change in water filtration depending on the soil compaction of the temporary irrigating canal dam

Dam soil density, $g/^{cm3}$		Water filtration rate, cm/hour	Cases of dam erosion
The inner half of the dam	The outer half of the dam		
0.9	0.9	25.6	4 cases
1.2	1.2	16.3	1 case
1.5	1.5	11.4	0
1.7	1.7	6.4	0
1.5	0.9	11.6	0
1.8	1.3	4.1	0

In addition, it turned out that the inner half of the dam basically needs to be compacted to a greater extent than its outer part. If the inner part of the dam is compacted more than 1.8 $g/^{cm3}$, then it is possible to leave the outer part uncompacted. However, if the preparation of temporary irrigating canal is fully mechanized, then the dam compaction remains an open issue, which significantly affects the loss of irrigation water. At the present time, the compaction process of temporary irrigating canal dams in farms is carried out by rolling tractor wheels or manually with ketmen. [8].

Research work has been carried out for several years in order to mechanize the technological process of dams' compaction and the development of a dam compactor. As a result of the experiments carried out, the design of the dam compactor and the types of operating bodies were selected. It was revealed that the main parameters of the dam compactor affecting the compaction process of temporary irrigating canal dams are cone roller diameter, length and width of the plate compactor, and the angle of dam nip. [6.7]. These parameters have been substantiated by theoretical and experimental studies.

The optimal values of these parameters were determined by mathematical planning of the experiment.

Table 2 shows the limits and variation levels of the above factors.

Table 2. Limits and levels of factors' variation

Factors	Designation		variation limit	Factors' level		
	actual	conditional		lower limit (-1)	base (0)	upper limit (+1)
1	2	3	4	5	6	7
Cone roller diameter, mm	D_k	X_1	50	450	500	550
Length of plate compactor, mm	L	X_2	50	550	600	650
Width of plate compactor, mm	α	X_3	30	300	330	360
Dam nip angle of dam compactor's compacting operating bodies, deg	β	X_4	5	30	35	40

The experiments were carried out according to plan B $_4$ with 1/2 replica, according to which the number of experiments is less than when using other plans. The order of the experiments is randomized using a table of random numbers.

The task of the research was to find, by varying the values of the factors, such a condition for the flow of the technological process, in which the maximum compaction of the soil is achieved.

The mathematical model of the research object is the response function of an equation linking optimization parameters with controlled factors. [6].

The results of the experiments were processed on a Pentium personal computer using a multiple regression analysis program. The hypothesis of variance uniformity in the same non-repeated experiments was tested using the Cochran's test, and the significance of the regression coefficients was determined by the Student's criterion.

The adequacy of the process model was checked by the Fisher criterion. After processing the experimental data and evaluating the coefficients' significance, the following regression equations describing the process of dam compaction were obtained:

- by the height of the temporary irrigating canal dam:

$$E_1 = 14{,}8413 + 1{,}3333\mathrm{X}_1 + 2{,}6296\mathrm{X}_2 + 2{,}1667\mathrm{X}_3 + 0{,}2778\mathrm{X}_4 + 0{,}5000\mathrm{X}_1\mathrm{X}_2 + 0{,}2500\mathrm{X}_1\mathrm{X}_3 + 0{,}2917\mathrm{X}_1\mathrm{X}_3 - 1{,}0238\mathrm{X}_3^2 - 0{,}8333\mathrm{X}_3\mathrm{X}_4 + 0{,}9762\mathrm{X}_4^2 \ ; \ cm \quad (1)$$

- by the compaction degree of the temporary irrigating canal dam:

$$E_2 = 1{,}2997 + 0{,}0984\mathrm{X}_1 + 0{,}0761\mathrm{X}_2 + 0{,}0703\mathrm{X}_3 + 0{,}0130\mathrm{X}_1\mathrm{X}_2 - 0{,}0182\mathrm{X}_1\mathrm{X}_4 + 0{,}0672\mathrm{X}_2^2 + 0{,}0095\mathrm{X}_2\mathrm{X}_3 - 0{,}0465\mathrm{X}_3^2 + 0{,}0530\mathrm{X}_4^2 \ ; \ g/cm^3 \quad (2)$$

By jointly solving the regression equations E_1 and E_2 under the conditions$E_1 \rightarrow \max$ and $1{,}4 \frac{g}{cm^3} \leq E_2 \leq 1{,}6 \frac{g}{cm^3}$, the optimal parameters of the dam compactor for such working conditions under which soil compaction would be maximal were determined (Table 3).

Table 3. Optimal values of factors

Values of factors	Main factors			
	X_1	X_2	X_3	X_4
	D_k	L	α	β
encoded	+0,7866	+0,8585	+1,000	-1,000
natural	539,33	642,92	360	30
rounded-off	540	643	360	30

It follows from Table 3 that in order to bring the compaction degree of the temporary irrigating canal dam to the required value and ensure its greatest height, the following parameters must correspond:

$$D_k = 540\ mm;\quad L = 643\,mm.;\ \alpha = 360\,mm.;\ \beta = 30^0.$$

Based on the obtained optimal values of the main parameters, an improved dam compactor was manufactured and, when tested in the field, showed a significant increase in productivity relative to existing ones and provided a compaction degree to agrotechnical requirements in one pass of the unit.

4. Conclusions

1. According to the results of experimental studies, it can be concluded that the soil condition of the dam characterized by a density of 1.5 $g/^{cm3}$ does not allow its erosion and basically, it is necessary to compact the inner part of the temporary irrigating canal dam to a greater extent.
2. Soil compaction of the temporary irrigating canal is accompanied by plastic deformations of the soil, as a result of which the geometric dimensions of the dam decrease. Therefore, the height of the dam as a criterion for the necessary water layer during irrigation should be reduced minimally.
3. Experimental studies have shown that in order to obtain the greatest effect of dam compaction, the main parameters of the dam compactor should be as follows: a large diameter of the cone roller 540 mm, ski length 643 mm, ski width 360 mm and a dam circumference angle of 30 degrees.
4. On the conducted modes of operation, the indicators of the dam compactor were as follows: the dam height after compaction was within 20...22 cm, the dam base width was within 73...75 cm and the soil density of the dam was within 1.38...1.49 $g/^{cm3}$, which met the requirements for irrigation works cut by existing ditchers.

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