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Optimization of the set of loading - transportation machines

*Z.T.*Maksudov*, and *S.M.* Mirkholikov

Tashkent State Transport University, Tashkent, Uzbekistan

Abstract. In this case, the road is being restored The results of scientific research on the effective use method and calculation of the used excavator-transport machinery set are being seen. The main indicators considered are the labor cost of loading and transporting soils used in road pavement rehabilitation and the performance of road transport. In this work, the optimal operational parameters of the set of machines used in the construction and repair of the road were determined.

1 Introduction

Road construction works mainly consist of construction of road elements, i.e. road foundations and pavements. Road foundations: soil (soil) road base; one- or two-layer gravel and cobblestone road foundations; One or two-layer asphalt concrete pavement construction works are performed by a set of machines. The machine set consists of three different types of road construction machines, including: basic head-booting machines; It consists of auxiliary machines and reserve machines.

The road equipment included in the machine set is selected taking into account the type of work, i.e., the construction or repair of the road base or pavement, the technology of the work process, the volume of work, and the interdependence and main indicators of the road construction machines.

When choosing road construction machines and equipment, the volume of work performed during the day, the daily distance traveled, the technical indicators of the road, the compatibility of road equipment with each other (despite differences in types and models of road construction machines and equipment, produced by various enterprises and firms from different countries, the main indicators and technical specifications of road machinery are very similar to each other). In addition, it is necessary to pay attention to the situation and features of the organization of work.It is known that to optimize any considered problem or solution, it is necessary to first of all choose the criterion of optimality and, based on this criterion, optimize the indicators of the level that gives the solution with high efficiency. Optimizing the set of machines, that is, forming the optimal set of machines, can solve this problem by optimizing the work volume or the required number of the main leading machines in the set, the cost of work, or the indicators of the machine integrally connected with it in the technological process.

*Corresponding author: maksudov-55@mail.ru

2 Methods and objectives of the research

The aim of the scientific research work is to optimize the composition of set of machines that would perform coherently resulting in better efficiency and quality. In this work, the construction of the ground base of the highway is aimed at forming an optimal set of vehicles. The set of machines that perform this kind of work includes: the design and calculation of the excavator-transport leading machine set during the construction of the road base. The set of machines for the construction of the road base includes the following machines: bulldozers, motor graders, light, medium and heavy compaction machines, water sprinklers and spare machines, dump trucks and excavators.

The working condition of transporting the soil used in the construction of this road base is analyzed here.The main techniques that speed up the road construction process and control the process are the excavator-transport pair, the organization of timely delivery of soil to the road, and the continuous operation of other machines in the complex during the day.

By optimizing the work of the excavator-transport pair, it is possible to optimize the entire set of machines based on their indicators, in which the main indicators are included in the optimality criteria, and the optimization of the intended indicators in analytical and graphoanalytical methods is the basis of the solution, defined by the following expressions :

$$\Pi_E = \varphi(N_i)$$

$$C_T = \varphi(N_i)$$

The efficiency of this pair of interconnected machines depends on the organization of the work, the work front, the operation of the technological machines in the set, the technical conditions of road equipment and vehicles. It is important that the working process of the excavator-transport set matches the main indicators of these techniques, that is, the proportionality of these indicators.

The main direction of optimizing the performance of the excavator-transport set is to reduce the unintended stops in the work process of these machines, that is, to minimize them or to optimize the number of machines in the set.

Forming the optimal set of machines developed on the basis of the methodology ensures the optimal number of vehicles that ensure the continuous and efficient use of loaders and other assembling machines in the set of machines, the loss of the working time of the excavator, t_{ek} and the increase in the productivity of all machines included in the set of machines.

3 Results and discussion

The results of the experimental time measurement of the loading time of the single-bucket excavator "DAEWOO W 210" to the vehicle "MAN 16.220" are presented in table 1.

Table 1. Excavator "DAEWOO W 210" loading time (t_y) timing results

Measurement number	Number of loadings	Loading duration t_y, p	Measurement number	Number of loadings	Loading duration t_y, p
1	6	0.053	16	7	0.063
2	7	0.064	17	7	0.061
3	6	0.055	18	6	0.054
4	7	0.066	19	6	0.051

Continuation of table № 1

Measurement number	Number of loadings	Loading duration t_y, p	Measurement number	Number of loadings	Loading duration t_y, p
5	7	0.061	20	7	0.67
6	6	0.057	21	6	0.049
7	6	0.052	22	7	0.066
8	7	0.062	23	6	0.052
9	6	0.050	24	6	0.055
10	7	0.062	25	7	0.063
11	7	0.065	26	7	0.061
12	6	0.055	27	6	0.054
13	7	0.061	28	6	0.051
14	6	0.052	29	7	0.063
15	7	0.063	30	6	0.052

The analysis of table 1 shows that the average loading time of the soil by the DAEWOO W 210 excavator with the MAN 16.220 dump truck is t_y^{av} as follows.

$$t_y^{av} = 0.058 \text{ s or } t_y^{av} = 32 \text{ sec}$$

Based on N_i the average value of the t_y^{av} loading time, we determine the total time of loading the truck with the following expression:

$$T_y = \frac{t_y^{av} N_i}{n},$$

$$T_{y_3} = \frac{t_y^{av} N_i}{n} = \frac{0.058 \cdot 3}{1} = 0.174$$

$$T_{y_4} = \frac{t_y^{av} N_i}{n} = \frac{0.058 \cdot 4}{1} = 0.232$$

$$T_{y_5} = \frac{t_y^{av} N_i}{n} = \frac{0.058 \cdot 5}{1} = 0.290$$

$$T_{ю_6} = \frac{t_y^{av} N_i}{n} = \frac{0.058 \cdot 6}{1} = 0.348$$

T_{yi} for the remaining values N_i of

Table 2 Download time T_{yi} calculation results

N_i	3	4	5	6	7	8	9	10	11
T_{yi}	0.174	0.232	0.290	0.348	0.406	0.464	0.522	0.530	0.638

The time spent on hauling a dump truck for one trip $T_{ц.а}$ is calculated using the following expression:

$$T_{ц.а} = \frac{2L}{V_{av}} + t_{yo} = \frac{2 \cdot 8.5}{55} + 0.019 = 0.328$$

Taking into account the t_{ek} working time of one cycle of motor transport, the time spent loading the excavator "DAEWOO W 210" and the time spent loading the $T_{ц.а}$ dump truck "MAN 16.220" t_{ac} are calculated with the following expression, and the results are included in Table 2:

$$t_{ek} = T_{ц.а} - \frac{t_y^{av} N_i}{n}$$

when the number of trucks $N = 3$

$$t_{ek} = T_{ц.а} - \frac{t_y^{av} N_i}{n} = 0.328 - \frac{0.058 \cdot 3}{1} = 0.154$$

when the number of trucks $N = 4$

$$t_{ek} = T_{ц.а} - \frac{t_y^{av} N_i}{n} = 0.328 - \frac{0.058 \cdot 4}{1} = 0.096$$

when the number of trucks $N = 5$

$$t_{ek} = T_{ц.а} - \frac{t_y^{av} N_i}{n} = 0.328 - \frac{0.058 \cdot 5}{1} = 0.038$$

In the following calculations, with a value of ni equal to zero, the excavator parking time is excluded, since the values are negative, which in turn indicates the beginning of the waiting time for loading vehicles, in other words, the beginning of the dump truck parking time.

Now the stop time of the dump truck during loading is calculated by the following expression:

$$t_{ac} = \frac{t_y^{av} N_i}{n} - T_{ц.а}$$

when the number of trucks $N = 6$

$$t_{ac} = \frac{t_y^{av} N_i}{n} - T_{ц.а} = \frac{0.058 \cdot 6}{1} - 0.328 = 0.020$$

when the number of trucks $N = 7$

$$t_{ac} = \frac{t_y^{av} N_i}{n} - T_{ц.а} = \frac{0.058 \cdot 7}{1} - 0.328 = 0.078$$

In this way, we calculate the t_{ac} number of cars and the number of cars in N_i other values and enter them into table 2.

And t_{ac} values of Π_E the loading and transport machines included in the road repair excavator-transport machine set, we determine the work productivity of the machine set t_{ek} and the cost of loading and unloading works T_u with the following expression.
We will simplify the expression for calculating the productivity of the set of machines Π_E and the costs of transportation and unloading work, taking into account some values T_u.

$$\Pi_E = \frac{GK_T KK_{IG}}{\gamma\left(T_{ц.ek} + t_{ek}\right)} = \frac{10 \cdot 0.86 \cdot 0.95 \cdot 0.96}{1.5\left(0.009 + t_{ek}\right)} = \frac{7.843}{1.5\left(0.009 + t_{ek}\right)} = \frac{5.23}{0.009 + t_{ek}}$$

result after simplification

$$\Pi_E = \frac{5.23}{0.009 + t_{ek}}$$

Now we calculate the performance of the excavator-transport machine set t_{ek} based on different values of and include the results in table 3:
when the number of trucks $N = 3$

$$\Pi_E = \frac{5.23}{0.009 + t_{ek}} = \frac{5.23}{0.009 + 0.154} = 32.09 \quad \text{m3 /s}$$

when $N = 4$

$$\Pi_E = \frac{5.23}{0.009 + t_{ek}} = \frac{5.23}{0.009 + 0.096} = 49.81 \quad \text{m3 /s}$$

when $N = 5$

$$\Pi_E = \frac{5.23}{0.009 + t_{ek}} = \frac{5.23}{0.009 + 0.038} = 111.28 \quad \text{m3 /s}$$

when $N = 6$

$$\Pi_E = \frac{5.23}{0.009 + t_{ek}} = \frac{5.23}{0.009 + 0} = 581.1 \quad \text{m3 /s}$$

Π_E value of N_i ni in other values, because the time of $N \rangle 6$ the excavator's halting time is t_{ek} eliminated, therefore, Π_E the value of ni will not change in further calculations $\Pi_E = const$, i.e. $\Pi_E = 581.1$ m^3/s.

According to the results of the experimental research, the performance of the excavator "DAEWOO W 210" machine set, as well as the value determining the work volume of the machine set and the truck dumper "MAN 16.220" in the set $\Pi_E = f(N_i)$, is presented in Figure 1.

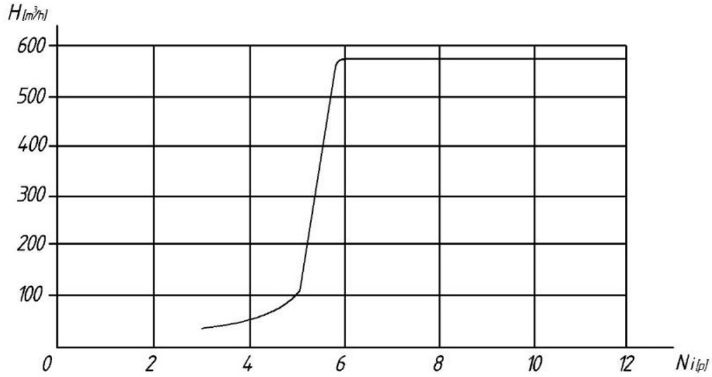

Fig. 1. Performance dependence graph of a set of machines for dump truck "MAN 16.220"

In this scientific research work, we calculate the cost of 1 m^3 of loading and unloading of a set of machines for soil transportation T_u with the following expression.

cost of work (T_u) t_{ac} at different values, we simplify the expression based on some indicators and reduce it to the following expression:

$$T_u = \frac{\gamma}{2GK_{IP}K_{IG}}\left[C_{c-m}\left(T_{ц.a} + t_{ac}\right) + 2G_k L\right] + \frac{C_{M-c_{ek}}}{П_E} + P_П + C_{ц.m} =$$

$$= \frac{1{,}50}{2\cdot 10\cdot 0.98\cdot 0.96}\left[20000\left(0.328 + t_{ac}\right) + 2\cdot 1200\cdot 8.5\right] + \frac{25600}{П_E} + 1250 + 4200 =$$

$$= 0.08\left[6560 + 20000t_{ac}\right]\frac{25600}{П_E} + 5450 = 524.8 + 1600t_{ac} + \frac{25600}{П_E} + 5450 =$$

$$= 5974.8 + 1600t_{ac} + \frac{25600}{П_E}$$

So, to calculate the cost of work T_u, we get the following expression.

$$T_u = 5974.8 + 1600t_{ac} + \frac{25600}{П_E}$$

We calculate the cost of work at different values of the excavator t_{ac}-transport machine set leading the set of machines used in the restoration of the road surface: N_i

when $N = 3$

$$T_u = 5974.8 + 1600\cdot t_{ac} + \frac{25600}{П_E} = 5974.8 + 1600\cdot 0 + \frac{25600}{32.09} = 6772.6 \quad \text{sum/m3}$$

when $N = 4$

$$T_u = 5974.8 + 1600 \cdot t_{ac} + \frac{25600}{\Pi_E} = 5974.8 + 1600 \cdot 0 + \frac{25600}{49.81} = 6408.8 \quad \text{sum/m3}$$

when $N = 5$

$$T_u = 5974.8 + 1600 \cdot t_{ac} + \frac{25600}{\Pi_E} = 5974.8 + 1600 \cdot 0 + \frac{25600}{111.28} = 6168.1 \quad \text{sum/m3}$$

when $N = 6$

$$T_u = 5974.8 + 1600 \cdot t_{ac} + \frac{25600}{\Pi_E} = 5974 \cdot 8 + 1600 \cdot 0.02 + \frac{25600}{581.1} = 6050.9 \quad \text{sum/m 3}$$

when $N = 7$

$$T_u = 5974.8 + 1600 \cdot t_{ac} + \frac{25600}{\Pi_E} = 5974.8 + 1600 \cdot 0.078 + \frac{25600}{581.1} = 6143.7 \quad \text{sum/m 3}$$

working cost of the set of machines T_u and t_{ac} the hardness at different values, calculated results are entered into Table 2.

Table 3. The results of calculating the indicators of a set of machines

No	Number of trucks N_i	Machine set performance Π_E, m³/s	Excavator stop time t_{ek}, p	Truck stop time t_{ac}, p	Loading and unloading costs T_u, sum/m³
1	3	32.09	0.154	0	6772.6
2	4	49.81	0.096	0	6488.8
3	5	111.28	0.038	0	6168.1
4	6	581.1	0	0.020	6050.9
5	7	581.1	0	0.078	6143.7
6	8	581.1	0	0.136	6236.5
7	9	581.1	0	0.194	6329.3
8	10	581.1	0	0.252	6422.1
9	11	581.1	0	0.310	6514.8

Using the results of the research presented in Table 3, we make T_u a graph of the relationship between the cost $T_u = f(N_i)$ of loading and transporting soil in the set of machines and the number of dump trucks in the set of machines, the N_i graph is shown in Figure 2.

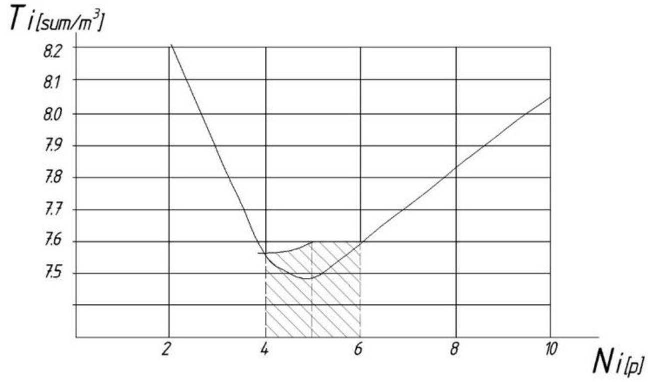

Fig. 2. The cost of a set of machines and dump truck "MAN 16.220" number dependence graph

4 Conclusions

Based on the results of scientific research, the optimization of the composition of loading and transport machines ensures the effective use of other types of machines involved in this process. The results obtained prevent the idle standing of composite machines in the machine unit during the working process, i.e. stop without work. As seen in figure 3.4. earth works, for example, in the restoration of the road base, which is considered as a head-booting machine in the optimal set of composite unit, which ensures the continuous operation of the excavator brand "DAEWOO W 210" ($t_{ek} \to \min$) "The optimal number of MAN 16.220" dump trucks is equal to $N_{\exp} = 5$; with this optimal number, high operation efficiency is obtained.

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