## Mathematical Model of the Probability of Road Repairs

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**Abstract.** The article presents the results of the studies carried out to identify various types of deformation and destruction in the system of construction "Road clothes - Subgrade" on operated roads, in which it is necessary to carry out repair work in a short time to ensure continuous movement of vehicles. Depending on the state of the system of construction "Road clothes - Subgrade", mathematical models are proposed to find the probability of repair work.

**Keywords:** Automobile roads, construction "Road clothes - Subgrade", natural and climatic factors, probability of repair, reconstruction, types of deformation and destruction, types of repairs, vehicle loads.

**INTRODUCTION**

The state of the system of construction "Road clothes - Subgrade" during operation under the influence of transport load, vehicle traffic intensity and weather and climatic factors undergoes changes not only by years and seasons of the year. When designing the structure and calculating the strength of the system of construction "Road clothes - Subgrade", deterministic values of the strength characteristics of the materials used in the layers of clothing and roadbed are taken, while in the mode of operation of highways all existing transport loads and natural and climatic factors are probabilistic.

The condition of the system of construction "Road clothes - Subgrade" during the operation of highways can be assessed by the following indicators: strength and evenness (longitudinal and transverse), roughness, surface roughness.

The standard level of safety of the system of construction "Road clothes - Subgrade" is understood as the state of the road section in which the structural indicators correspond to the permissible values, and no repair is required.

During operation, due to the impact of transport loads and weather and climatic factors, small temperature cracks, crack mesh and other defects on its surface appear in the system of construction "Road clothes - Subgrade", which leads to a gradual decrease in structural bonds in the system as a whole.

The presence of small cracks, barely visible potholes and other defects, which at first glance seem insignificant, is in fact an already formed problem that requires speedy elimination. The danger of delay is that, under the influence of external influences, a small defect is transformed over time into a large-scale damage, which is more difficult and expensive to eliminate.

Timely elimination of small defects is important for a variety of reasons:

- moisture penetrates into the cavity of small cracks and potholes and accumulates there. This has a particularly detrimental effect on the integrity of the coating in winter, when, as a result of temperature changes, the volume of water constantly changes, which leads to an increase in the scale of deformations.

- in summer, dust and dirt is packed into deformed areas, which in areas with low traffic intensity can lead to germination of plants, the root system of which will aggravate the destruction of the coating.

Taking into account the above factors, cracks and other defects that appeared during the operation of highways must be eliminated in the shortest possible time, thereby maintaining the quality of its condition and integrity.

If defects are not repaired in a timely manner, they will adversely affect the speed and safety of vehicles and road capacity.

Minor defects can be repaired by making routine repairs that take less time to repair. If current repairs are not carried out in a timely manner, then, firstly, the area of defects will increase and, secondly, the operational condition of road pavements will decrease, and this will lead not only to large costs for major repairs or reconstruction of roads, but also more time will be required for repairs.

Currently, by road of the Republic of Uzbekistan, the transportation of passengers by road in certain regions is 98-99%, and cargo - 90-92%. Therefore, in order to ensure the speed and safety of vehicles with minimal travel time on sections of the road, it must function continuously. In case of occurrence of various deformations and defects in the system of construction "Road clothes - Subgrade" during the operation of motor roads, one or another type of repair of motor roads should be carried out in a timely manner, with minimal costs and in a short time; this is a major part of the mass road maintenance system.

**METHOD AND RESULTS**

During the operation of highways, the system of construction "Road clothes - Subgrade" is influenced by various external factors that contribute to the appearance of various types of deformations and defects that lead to its gradual destruction. The appearance of deformations and destructions on the surface of the system of construction "Road clothes - Subgrade" leads to a decrease in its strength, deterioration of the evenness and roughness of the surface of the coating, as well as the appearance of rutting.

In this regard, studies were carried out to determine the causes of various deformations in the system of construction "Road clothes - Subgrade" due to the impact of vehicle load and climatic factors during the operation of highways [1, 2, 3, 4, 5].

These studies have shown that permanent deformations arise from the effect of repeated loads, which later lead to the destruction of the system of construction "Road clothes - Subgrade".

Predicting cracks in asphalt concrete pavements helps make decisions about timely repair and improvement of the design of roads and road surfaces.

Temperature cracks (transverse and longitudinal) and crack grids on pavement surfaces are the most common type of pavement defects. Currently, one of the main problems of the road sector is the emergence of small temperature cracks and a network of cracks on road surfaces, the main reasons for the appearance of which are the effects of loads from cars and natural and climatic factors.

On the road, there is a penetration of surface water into the system of construction "Road clothes - Subgrade" through these deformations, which leads to destruction. And this entails a decrease in the speed and safety of vehicles. Therefore, regardless of the types of deformation, it is necessary to carry out timely repair work while the deformed area has a small area.

The studies carried out and the materials obtained on the roads of the Republic of Uzbekistan show that the state of the whole system of construction "Road clothes - Subgrade" under the influence of transport loads and weather and climatic factors, i.e. transport and operational state, gradually deteriorates during its operation.

And this leads to a decrease in the speed and safety of movement, the comfort of the passage of passengers and the integrity of goods, and the passage on such sections of the road takes more time.

On the selected roads for the study, the intensity and speed of movement, throughput, strength, and evenness of roads were determined. In addition, the timing of current and overhaul, and reconstruction of operated roads, depending on the types of deformations and destruction, was studied.

Frequently occurring different types of deformation (cracks, crack grid, track) and destruction on the examined different roads are shown in Figure 1.

The appearance of deformation and destruction in the system of construction "Road clothes - Subgrade" during the operation of highways is possible from the use of low-quality materials and non-compliance with construction technology, as well as from the impact of transport loads and unfavorable meteorological conditions.

The appearance of any deformation and destruction in the system of construction "Road clothes - Subgrade" requires timely repair in order to preserve it from further destruction.

It is known that according to ShNK 4.02.68-07 "Collections of resource estimate standards for repair and construction work. Collection 68 "gives the time spent on the production of road repairs.

For example, cracks that have appeared in the asphalt concrete pavement can be eliminated by carrying out routine repairs.

The current repair technology is carried out as follows: first, cracks are cut for alignment, then cracks are cleaned and filled with bitumen or bitumen mastic with filling the surface with sand, and compaction (see Table 68-19 of ShNK 4.02.68-07) [6].

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**Figure 1.** Types of cracks (longitudinal and transverse), crack grid, track and destruction found on highways of the Republic of Uzbekistan

For current repair of 100 m long asphalt concrete pavement cracks according to ShNK 4.02.68-07, the time norm is 1.4 machine-hours of work of drivers [6]. This means that in a short time it is possible to mechanically repair cracks on asphalt concrete pavements. The process of current repair to eliminate the crack of the asphalt concrete pavement is given in Figure 2.

In ShNK 4.02.68-07 "Collections of resource estimate standards for repair and construction work. Collection 68 "gives the time spent on the production of major repairs and reconstruction of roads.

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a) b) c)

**Figure 2.** Technology of current repair by filling cracks: a - cutting by alignment of cracks; b - crack cleaning by compressor; c - filling of cracks with bitumen mastic.

Mathematical modeling of the process of repair and reconstruction of roads and road structures has been studied in many studies, in particular in works [7, 8, 9, 10, 11, 12, 13, 14].

The road can be considered as a single-channel mass service system: by carrying out routine repairs, cracks can be eliminated, and major repairs are required to eliminate destroyed sections of the road, increase throughput, traffic safety, its strength and evenness. If the speed, safety and comfort of vehicles, and the capacity of the road are reduced by increasing the traffic intensity, then it is necessary to reconstruct the existing road.

Let the intensity of the flow of vehicles on a road be distributed according to Poisson's law with a parameter , i.e.,  cars pass through it per unit of time.

We will assume that:

- the capacity of the motor road is distributed according to the exponential law with the parameter , i.e. the average time of the capacity of the motor road is equal to  units of time;

- the road failure-free operation time is distributed according to the exponential law with the parameter  (in other words, the average failure-free operation time is equal to ), i.e. in the system of construction "Road clothes - Subgrade" various deformations and destruction possible in a short time  during its operation may appear with probability ;

- the time of the current repair of the motor road is distributed exponentially with the parameter , i.e. the current repair of the motor road can be completed in a short time  with probability .

- the time of overhaul or reconstruction of the road is distributed exponentially with the parameter , i.e. overhaul or reconstruction of the road can be completed in time  with probability .

Here and in the future, the symbol  **(**, , ) will denote a negligible summand in comparison with the rest in the sum.

Also, let various small and temperature cracks appear in the system of construction "Road clothes - Subgrade" with probability  during the current repair of the highway, and these defects will be eliminated in a short time with a probability  for the complete functioning of the highway.

To find the probabilities of various states of the highway based on the results of [15, 16], we consider two cases.

**Case I.** Routine repair work is carried out quite quickly compared to major repairs, or reconstruction of roads, i.e.  and  (here we mean a small amount of major repairs, as well as reconstruction is carried out on short sections of the road).

On the road, the probability of safe passage of the flow of cars in normal conditions will be equal to:

. (1)

If current repairs are carried out on the road, then its probability will be equal to:

. (2)

If a planned overhaul or reconstruction is carried out on the road, then their probability will be equal to:

. (3)

If the road is in free movement mode, then its probability is

. (4)

Here  means the average time for overhaul and reconstruction of the highway, and  means the average time for the current repair of the highway.

The following designations are entered here:

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**Case II.** The system of construction "Road clothes - Subgrade" does not deform or break during the specific period under consideration, or it is extremely rare, and the small cracks that have appeared can be eliminated by carrying out routine repairs in a fairly short time, i.e. ,  and .

In this case, the probability that the road will function normally and the flow of cars will move unhindered will be equal to:

. (5)

On the road, the probability of current repairs will be equal to:

. (6)

If a major overhaul or reconstruction is carried out on the road, then their probability will be equal to:

. (7)

If the road has a free movement mode, then its probability will be equal to:

. (8)

The following designations are entered here:

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The results of the study make it possible to determine the probability of repairing the system of construction "Road clothes - Subgrade" of highways.

**CONCLUSION**

Thus, based on the results of the studies performed, the following conclusions and recommendations can be made:

1. If normal traffic conditions are provided on the road, then the probability of safe passage of the traffic under normal conditions is determined by formula (1) for the first case, by formula (5) for the second case.

2. If current repair is carried out on the road, then its probability is determined by formula (2) for the first case, and formula (6) is applied for the second case.

3. If a major repair or reconstruction is carried out on a road, then their probability is determined by formula (3) for the first case, by formula (7) – for the second case.

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