Impact of the temperature factor on the quality of road clothes

R. Khalilov

Abstract. The article deals with the problems of designing roads associated with short-term and relatively long-term rhythms of temperature fluctuations. The results of temperature changes in the long-term cycle in the Jizzakh region of Uzbekistan are presented. Based on the importance of the temperature factor, measures to prevent the process of destruction of asphalt concrete road surfaces are recommended.

1 Introduction

On the eve of 2021, in his message to Oliy Majlis of the Republic of Uzbekistan, the President, Shavkat Mirziyoev stressed that “We are seriously concerned about the deterioration of the environmental situation in the region and around the world” [1].

This deterioration of the environment leads to diseases of the population [2], changes in natural processes [3], complicates anthropogenic activity [4-6].

Thus, the presence in the atmospheric air of hundreds of pollutants that are not characteristic of its natural composition has led to a number of problems, including the “greenhouse effect”. Water vapor, carbon dioxide \( \text{CO}_2 \), methane \( \text{CH}_4 \), nitrous oxide \( \text{N}_2\text{O} \) absorb thermal radiation reflected by the earth's surface, which leads to additional accumulation of heat in the air, the earth's crust and oceans. Experts consider this process to be the cause of global warming of the planet, since gases delay the long-wave thermal radiation of the Earth and prevent the escape of heat into space [7].

The main source of greenhouse gases is the result of the process of burning hydrocarbon fuels. At the same time, the largest amount of greenhouse gases is formed during the operation of vehicles. For example, the emission of carbon monoxide \( \text{CO}_2 \) per 1 km by trucks with a carrying capacity of more than 35 tons is 0.051 ... 0.091 kg per ton of cargo, and by type of passenger transport per passenger: cars - 0.124 kg, two-wheeled vehicles - 0.083 kg, city buses - 0.067 kg, intercity buses – 0.034 kg [8, 9].

If we take into account that more than 400 million cars are used on the roads of the world, and from 39 to 72 road construction machines are used to construct 1 km of pavement with asphalt concrete, then we can judge the “contribution” of vehicles to the greenhouse effect [4].
According to literature data, transport accounts for about 62% of world oil consumption, which in the future until 2035 will grow by approximately 1.4% per year and reach 82% [9, 10].

Climate change is fraught with a wide variety of negative consequences for transport infrastructure. For road transport, this is due to an increase in the number of fogs, showers, snow avalanches, sandstorms, etc. An increase in precipitation can significantly affect the condition of roads. Structural integrity of roads may be compromised, which may require more frequent repair and restoration work. Rising temperatures and long periods of heat will soften the asphalt pavement. Temperatures above 30°С can lead to transport equipment failures. Dry and hot summers lead to deterioration and subsidence of the road surface, which leads to a decrease in its performance. There are problems of overheating of cars and tire wear [5]. Increase in temperature may increase the need for the use of refrigeration equipment, which is associated with an increase in the cost of cargo transportation, especially in the warm areas of the region [5, 9, 10].

The increase in water flow expected in some regions of the countries will cause river floods. This phenomenon will have the most catastrophic consequences for the roads laid on the flood plains or crossing them.

The climatic provision of the road industry is large-scale, which is due to the large length of transport routes, measured by many hundreds and thousands of kilometers [5, 9, 10]. Roads, being linearly extended structures, are laid across territories with different landscape structures and climatic conditions. Since the road network depends on weather conditions, we believe that it is necessary to scientifically substantiate the processes of the influence of the temperature factor on the road structure under the current and future state of the climate and its change.

The objective of the study was to analyze the causes of deformation of asphalt concrete pavements associated with short-term and relatively long-term rhythms of fluctuations in the temperature factor in the conditions of Uzbekistan and recommend measures to prevent it.

2 Methods

The object of the study was the sections of roads with asphalt concrete pavement, operated in the conditions of Uzbekistan, on the example of roads in the Jizzakh region.

The analysis of scientific, normative literature, Internet sources and technical projects is carried out. The method of observation and the field method of research were applied.

3 Results and discussions

The Law of the Republic of Uzbekistan states: “A highway is a complex of engineering structures designed for the movement of vehicles, ensuring their continuous and safe movement at a set speed, load, dimensions, as well as land plots provided for the placement of this complex, and the space above it in established limits” [11].

Depending on the intensity of traffic and importance in the general transport network, roads in Uzbekistan are classified into: public roads (international, state and local); streets of cities and other settlements; economic roads [12].

In Uzbekistan, the total length of the network of public roads is 209,000 km. More than 2 million vehicles move on the roads, of which 44% run on gasoline, 15% on diesel fuel and 41% on gas fuel. Motor transport of the republic is the source of 60% of all impurities in the atmospheric air [13].

The safe movement of vehicles on the road determines the quality of the pavement.
The following elements of pavement are distinguished: pavement—the upper part of the pavement, which receives forces from the wheels of vehicles and is directly exposed to atmospheric factors; base—a part of the pavement structure located under the pavement and providing, together with the pavement, the redistribution of stresses in the structure and the reduction of their magnitude in the soil of the working layer of the subgrade, etc. [14].

Based on the canons of the road business, the route should be designed with mutual coordination with the natural landscape, and the reliability of the road operation, at the lowest cost, should be ensured by the quality of the subgrade and road pavement. In turn, the quality of road surfaces is determined by the design, material science, and technological aspects. The dominant indicator among these aspects is the characteristics of road construction materials [15].

Pavements with layers made of various types of asphalt concrete are classified as non-rigid. In Uzbekistan, the most used material for pavement of roads is asphalt concrete. In the republic, asphalt concrete pavement consists of layers 3…7 cm thick of a mixture of crushed stone of different sizes taken in the required proportion, sand, stone flour and molten bitumen as a binder [16, 17].

Cloth with the use of viscous bitumen has a relatively low deformability. Therefore, even with small vertical deformations under repeated loading, tensile stresses from bending exceeding the permissible value may occur in them, this leads to the formation of cracks, which amount to 90…95 %, erosion damage –5…10 %, mainly in the areas of cracks, technological seams and only a fraction of a percent along the length are sections that have failed due to irreversible shifts in asphalt concrete, in places of temporary stops and parking lots.

We have studied the operating conditions of roads laid on the territory of the Jizzakh region. This is the largest industrial and tourist region of Uzbekistan, located in the center of the republic between the Syrdarya and Zarafshan rivers and covering an area of 20.5 thousand square kilometers. On the northern side of the region there are the Syrdarya region and Kazakhstan, on the southeast—Tajikistan, and on the west—Samarkand and Navoi regions [18].

The famous Silk Road, connecting the West with the East, ran through the territory of the region. In accordance with the classification, the road network includes highways of international importance—A-376 Jizzakh—Khavast; M-39 Tashkent—Termez; state—4R35Syrdarya... and local 4K 221 Dustlik sh. ... and others. The density of the road network indicates its importance in the Jizzakh region for the further economic development of this area.

We have analyzed the state of pavement depending on the state of the environment with an emphasis on the temperature factor.

In the Jizzakh region, fluctuations in atmospheric air temperature are observed from year to year in daily and annual periods. The difference between the average temperature, \( t_{av} \), of the coldest and warmest months is 26…30 °C. The difference between the absolute maximum and the absolute minimum is 77…80 °C.

The winter period is characterized by weather instability, cloudiness, frequent precipitation and changes in air temperature. The average monthly temperature in January, the coldest month of the year, ranges from 0 to \(-5.4 °C\). Low temperatures are observed in the northern part of the region and in the mountains. The absolute minimum air temperatures range from \(-29 to \(-34 °C\), the average absolute minimums from \(-18 to \(-26 °C\). A significant part of the territory of the Jizzakh region is characterized by moderate frosts. Winter is mild in most of the flat territory of the region, and in the far north and in the mountains it is moderately cold.
days on average 30…34 days lead to freezing of the soil. The greatest freezing depth
reaches 57 cm. The frost-free period is long for 210…223 days.

The period with air temperature above 0°C averages 319…345 days across the territory.

Summer is hot and dry. The average monthly temperature in July, the warmest month, is
26.8…31.2 °C in the flat area, and 16.2°C in the mountainous areas. The absolute
maximum air temperature throughout the territory reaches 45…47°

According to the meteorological station in Jizzakh, the average annual air temperatures
in a long-term (140 years) cycle are characterized by significant fluctuations.

It follows from the temperature series that with a general increase in average annual
temperatures, seven rhythms of their change can be distinguished: 1882-1921 fluctuation was within 0.14°
C, 1921-1931 – lowering of t_av by 0.55°C , then until 1941 increase to the level of 1921, after until 1951
again a decrease by 0.41° C. Then, over the course of twenty years, t av increased, and
since 1971 t_av of air decreased by 0.59 °C. Since
1981 until 2021, i.e. within 40 years t_av of air increased. In general, compared with the
period of 1882-1891 in 2012-2021 t_av of air is higher by 0.95 °C/10 years. The increase in
average annual temperatures is mainly due to higher average daily air temperatures in June
July (Fig. 1).

Fig. 1. Change in the average annual values of air temperature according to the meteorological station
in the city of Jizzakh for the period 1882 to 2021.
It is known that the strength of asphalt concrete is practically not affected by temperature from 0 to 20°C. The rate of development of elastic deformation depends on the properties of the binder, the temperature of the medium, and the composition of the mixture. Air temperature has a significant effect: at low temperatures, the elasticity modulus increases significantly and, accordingly, the deformability decreases, brittleness increases, and at elevated temperatures, the elasticity modulus and shear resistance decrease.

The level of thermal stresses in asphalt concrete decreases with increasing of coating thickness. This makes it possible to reduce the average integral cooling rates in them, increase the layer temperature, and reduce the amplitudes of daily temperature fluctuations. Frequent temperature drops in winter also contribute to the destruction of the road surface [15].

The quality of road pavement is also affected by other climate parameters, vehicle emissions and anthropogenic activities of industries, construction, impurities brought by the wind from other adjacent territories, etc.

On the territory of Uzbekistan, the Syrdarya, Amudarya and other water bodies are the regulator of the heat and moisture regime. According to the World Bank forecasts, by 2050, the water flow in the Syrdarya river basin may decrease by up to 5%, and in the Amudarya river basin by up to 15%, which will affect the humidity regime of the climate [21].

Due to the drying up of the Aral Sea, this process of heat and moisture exchange between air masses and the aquatic environment is not carried out. This, in turn, affects the climatic parameters of the region. The problem of the Aral Sea concerns not only Uzbekistan, but also neighboring countries.

An asphalt road has the following chemical composition: asphaltenes (a mixture of saturated heterocyclic compounds), resins (heterocyclic aromatic high molecular weight), oils (hydrocarbons of a simple structure), lime (Ca(OH)\(_2\) , CaO), cement dust (\(\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \), \(\text{CaSiO}_2 \), \(\text{CaO} \), \(\text{Al}_2\text{O}_3 \), \(\text{SiO}_2 \), \(\text{Fe}_2\text{O}_3 \)), phosphorus slag (\(\text{SiO}_2 \), \(\text{P}_2\text{O}_5 \), \(\text{CaO} + \text{MgO} \), \(\text{Fe}_2\text{O}_3 \), \(\text{Al}_2\text{O}_3 \)), hydraulic ash (\(\text{CaO} \), Mg, \(\text{SiO}_2 \), \(\text{Al}_2\text{O}_3 \), \(\text{Fe}_2\text{O}_3 \)), etc.

In Uzbekistan for roadway marking a number of organic and mineral paints, consisting of varnish, plasticizers, solvents, pigments and filler — chalk is used; this dust floats in the atmospheric air above the road and in the area adjacent to it, and eventually settles on the road surface. Pollutants emitted by transport, dispersing, settle on the carriageway. Based on traffic safety conditions, the smallest interval between the following cars one after another is determined by the speed of their movement and the condition of the surface of the coating and is 2 ... 3 seconds, with an intensity of 7 to 14 thousand cars/day. It should be noted that the trail from the ejection of one car is rolled up by others, leaving each its own additional trail [22].

When transporting various bulk cargoes, their particles enter the road surface due to partial losses. Chemical elements also enter in winter when de-icing agents are used. Dust storms are observed throughout the region. Solid fine and silty fractions of substances brought by wind or precipitation come from the atmosphere to the road surface. Atmospheric air is also polluted with dust in the process of anthropogenic activity. The dominant industry in the Jizzakh region is the production of building materials. There is a production for the manufacture of plastic products and cotton cleaning, there is a fish processing plant and a battery plant. Also, for example, the production of... There are a large number of mines that produce polymetallic ores containing lead, zinc, iron, raw materials for the manufacture of lime and limestone.

According to the Committee of Ecology of the Republic, emissions from the enterprise for the smelting of non-ferrous metals — aluminum, aluminum oxide, copper—zinc, lead, ...
4 Conclusion

Despite all the reconstruction work that is regularly carried out on asphalt concrete roads, a visual observation of the road network showed that a number of them need to improve their transport and operational condition, bringing their technical parameters in line with regulatory requirements for construction.

Based on the importance of the temperature factor on the process of destruction of asphalt concrete road surfaces, the following measures are recommended to prevent it:

1) when planning, designing, constructing and operating a motor road on each of its sections, take into account short-term and relatively long-term temporary effects of a temperature factor that varies in magnitude;

2) take into account the thermal and chemical factors of the anthropogenic activity of the industries of the region along with the thermal emissions of vehicles;

3) analysis of the temperature series for the period 1882-2021 showed that the temperature regime of the Jizzakh region has seven rhythms of change in average annual temperatures; since 1981 until 2021, i.e. within 40 years $t_{av}$-air increases, from the period 1882-1891 to 2012-2021 $t_{av}$ increased by 0.95 °C.

References


20. https://www.pogodaiklimat.ru/history
